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BOURNEMOUTH MEETING, 1919.

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ADDRESS

BY

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PRESIDENT.

THREE years of anxiety and stress have passed since the last Meeting of the British Association. The weight of the struggle which pressed heavily upon us at the time of the Newcastle Meeting in 1916 had increased so much in intensity by the Spring of 1917 that the Council, after consultation with the Local Committee at Bournemouth, finally decided to cancel the Summer Meeting of that year. This was the first time in the history of the Association that an Annual Meeting was not held.

We all rejoice to feel that the terrible ordeal through which the whole Empire has been passing has now reached its final phases, and that during the period of reorganisation, social and industrial, it is possible to resume the Annual Meetings of the Association under happier conditions. We have gladly and with much appreciation accepted the renewed invitation of our friends and colleagues at Bournemouth.

We are gathered together at a time when, after a great upheaval, the elemental conditions of organisation of the world are still in flux, and we have to consider how to influence and mould the recrystallisation of these elements into the best forms and most economic re-arrangements for the benefit of civilisation. That the British Association is capable of exerting a great influence in guiding the nation towards advancement in the Sciences and Arts in the most general sense there can be no question, and of this we may be assured by a study of its proceedings in conjunction with the history of contemporary progress. Although the British Association cannot claim any paramount prerogative in this good work, yet it can certainly claim to provide a free arena for discussion where in the past new theories in Science, new propositions for beneficial change, new suggestions for casting aside fetters to the advancement in Science, Art and Economics have first seen the light of publication and discussion.

For more than half a century it has pleaded strongly for the advancement of Science and its application to the Arts. In the yearly volume for 1855 will be found a report in which it is stated that 'The Objects for which the Association was established have been carried out in three ways: First, by requisitioning and printing reports on the present state of different branches of Science; secondly, by granting sums of money to small committees or individuals, to enable them to carry on new researches; thirdly, by recommending the Government to undertake expeditions of discovery, or to make grants of money for certain and national purposes, which were beyond the means of the Association.' As a matter of fact it has, since its commencement, paid out of its own funds upwards of 80,000*l*. in grants of this kind.

Developments Prior to the War.

It is twenty-nine years since an engineer, Sir Frederick Bramwell, occupied this chair and discoursed so charmingly on the great importance of the next to nothing, the importance of looking after little things which, in engineering, as in other walks of life, are often too lightly considered.

The advances in engineering during the last twenty years are too many and complex to allow of their description, however short, being included in one Address, and, following the example of some of my predecessors in this chair, I shall refer only to some of the most important features of this wide subject. I feel that I cannot do better than begin by quoting from a speech made recently by Lord Inchcape, when speaking on the question of the nationalisation of coal: 'It is no exaggeration to say that coal has been the maker of modern Britain, and that those who discovered and developed the methods of working it have done more to determine the bent of British activities and the form of British society than all the Parliaments of the past hundred and twenty years.'

James Watt.—No excuse is necessary for entering upon this theme, because this year marks the hundredth anniversary of the death of James Watt, and in reviewing the past, it appears that England has gained her present proud position by her early enterprise and by the success of the Watt steam engine, which enabled her to become the first country to develop her resources in coal, and led to the establishment of her great manufactures and her immense mercantile marine.

The laws of steam which James Watt discovered are simply these: That the latent heat is nearly constant for different pressures within the ranges used in steam engines, and that, consequently, the greater the steam pressure and the greater the range of expansion the greater

will be the work obtained from a given amount of steam. Secondly, as may now seem to us obvious, that steam from its expansive force will rush into a vacuum. Having regard to the state of knowledge at the time, his conclusions appear to have been the result of close and patient reasoning by a mind endowed with extraordinary powers of insight into physical questions, and with the faculty of drawing sound practical conclusions from numerous experiments devised to throw light on the subject under investigation. His resource, courage and devotion were extraordinary.

In commencing his investigations on the steam engine he soon discovered that there was a tremendous loss in the Newcomen engine, which he thought might be remedied. This was the loss caused by condensation of the steam on the cold metal walls of the cylinder. He first commenced by lining the walls with wood, a material of low thermal conductivity. Though this improved matters, he was not satisfied; his intuition probably told him that there should be some better solution of the problem, and doubtless he made many experiments before he realised that the true solution lay in a condenser separate from the cylinder of the engine. It is easy after discovery to say, 'How obvious and how simple,' but many of us here know how difficult is any step of advance when shrouded by unknown surroundings, and we can well appreciate the courage and the amount of investigation necessary before James Watt thought himself justified in trying the separate condenser. But to us now, and to the youngest student who knows the laws of steam as formulated by Carnot, Joule, and Kelvin, the separate condenser is the obvious means of constructing an economical condensing engine.

Watt's experiments led him to a clear view of the great importance of securing as much expansion as possible in his engines. The materials and appliances for boiler and machine construction were at that time so undeveloped that steam pressures were practically limited to a few pounds above atmospheric pressure. The cylinders and pistons of his engines were not constructed with the facility and accuracy to which we are now accustomed, and chiefly for these reasons expansion ratios of from two to threefold were the usual practice. Watt had given to the world an engine which consumed from five to seven pounds of coal per horse-power hour, or one-quarter of the fuel previously used by any engine. With this consumption of fuel its field under the conditions prevailing at the time was practically unlimited. What need was there, therefore, for commercial reasons, to endeavour still further to improve the engine at the risk of encountering fresh difficulties and greater commercial embarrassments? The course was rather for him and his partners to devote all their energy to extend the adoption of the engine as it stood, and this they did, and to the Watt engine,

consuming from five to seven pounds of coal per horse-power. Mankind owes the greatest permanent advances in material welfare recorded in history.

With secondary modifications, it was the prime mover in most general use for eighty years—*i.e.*, till the middle of last century. It remained for others to carry the expansion of steam still further in the compound, triple, and, lastly, in the quadruple expansion engine, which is the most economical reciprocating engine of to-day.

Watt had considered the practicability of the turbine. He writes to his partner, Boulton, in 1784: 'The whole success of the machine depends on the possibility of prodigious velocities. In short, without God makes it possible for things to move them one thousand feet per second, it cannot do us much harm.' The advance in tools of precision, and a clearer knowledge of the dynamics of rotating bodies, have now made the speeds mentioned by Watt feasible, and indeed common, everyday practice.

Turbines.—The turbine of to-day carries the expansion of steam much further than has been found possible in any reciprocating engine, and owing to this property it has surpassed it in the economy of coal, and it realises to the fullest extent Watt's ideal of the expansion of steam from the boiler to the lowest vapour pressure obtainable in the condenser.

Among the minor improvements which in recent years have conduced to a higher efficiency in turbines are the more accurate curvature of the blades to avoid eddy losses in the steam, the raising of the peripheral velocities of the blades to nearly the velocity of the steam impinging upon them, and details of construction to reduce leakages to a minimum. In turbines of 20,000 to 30,000 horse-power 82 per cent. of the available energy in the steam is now obtainable as brake horse-power; and with a boiler efficiency of 85 per cent. the thermo dynamic efficiency from the fuel to the electrical output of the alternator has reached 23 per cent., and shortly may reach 28 per cent., a result rivalling the efficiency of internal combustion engines worked by producer gas.

During the twenty years immediately preceding the war turbo generators had increased in size from 500 kilowatts to 25,000 kilowatts, and the consumption of steam had fallen from 17 lb. per kw. hour to 10.3 lb. per kw. hour. Turbines have become the recognised means of generating electricity from steam on a large scale, although they have not superseded the Watt engine for pumping mines or the drawing of coal, except in so far as it is a means for generating electricity for these purposes. In the same period the engine power in the mercantile marine had risen from 3,900 of the *King Edward* to 75,000 of the *Mauretania*.

As regards the Royal Navy, the engine power of battleships, prior

to the war, had increased from 12,000 i.h.p. to 30,000 s.h.p., while the speed advanced from 17 knots to 23 knots, and during the war, in ships of the *Queen Elizabeth* class, the power amounted to 75,000 s.h.p., with a speed of 25 knots. In cruisers similar advances were made. The i.h.p. of the *Powerful* was 25,000, while the s.h.p. of the *Queen Mary* was 78,000, with a speed of 28 knots. During the war the power obtained with geared turbines in the *Courageous* class was 100,000 s.h.p. with a speed of 32 knots, the maximum power transmitted through one gear wheel being 25,000 h.p., and through one pinion 15,500 h.p., while in destroyers, speeds up to 39 knots have been obtained. The aggregate horse-power of war and mercantile turbined vessels throughout the world is now about 35 millions.

These advances in power and speed have been made possible mainly by the successive increase in economy and diminution of weight derived from the replacement of reciprocating engines by turbines direct coupled to the propellers, and, later, by the introduction of reduction gearing between the turbines and the propellers; also by the adoption of water-tube boilers and of oil fuel. With these advances the names of Lord Fisher, Sir William White, and Sir Henry Oram will always be associated.

The Work of Sir Wm. White.—With the great work of the Royal Navy fresh in our minds, we cannot but recall the prominent part taken by the late Sir William White in its construction. His sudden death, when President-elect for 1913, lost to the nation and to the Association the services of a great naval architect who possessed remarkable powers of prevision and dialectic. He was Chief Constructor to the Admiralty from 1885 to 1901, and largely to him was due the efficiency of our vessels in the Great War.

White often referred to the work of Brunel as the designer of the *Great Eastern*, and spoke of him as the originator of the cellular construction of the bottoms of ships, since universally adopted, as a means of strengthening the hull and for obtaining additional safety in case of damage. Scott Russell was the builder of this great pioneer vessel, the forerunner of the Atlantic liners, and the British Association may rightly feel satisfaction in having aided him when a young man by pecuniary grants to develop his researches into the design and construction of ships and the wave-line form of hull which he originated, a form of special importance in paddle-wheel vessels.

So much discussion has taken place in the last four years as to the best construction of ship to resist torpedo attacks that it is interesting to recall briefly at the present time what was said by White in his Cantor Lectures to the Royal Society of Arts in 1906: 'Great attention has been bestowed upon means of defence against underwater torpedo attacks. From the first introduction of torpedoes it was re-

cognised that extreme watertight subdivision in the interior of warships would be the most important means of defence. Experiments have been made with triple watertight skins forming double cellular sides, the compartments nearest the outer bottom being filled, in some cases, with water, coal, cellulose, or other materials. Armour plating has been used both on the outer bottom and on inner skins.' He also alludes to several Russian ships which were torpedoed by the Japanese, and he concludes by saying: 'Up to date the balance of opinion has favoured minute watertight subdivisions and comparatively thin watertight compartments, rather than the use of internal armour, whose use, of course, involves large expenditure of weight and cost.'

The present war has most amply confirmed his views and conclusions, then so lucidly and concisely expressed.

While on the subject of steamships, it may perhaps be opportune to say one word as to their further development. The size of ships had been steadily increasing up to the time of the war, resulting in a reduction of power required to propel them per ton of displacement. On the other hand, thanks to their greater size and more economical machinery, speeds have been increased when the traffic has justified the greater cost. The limiting factor to further increase in size is the depth of water in the harbours. With this restriction removed there is no obstacle to building ships up to 1,000 feet in length or more, provided the volume and character of the traffic are such as to justify the capital outlay.

Tungsten Steel.—Among other important pre-war developments that have had a direct bearing upon the war, mention should be made of the discovery and extensive use of alloys of steel. The wonderful properties conferred upon steel by the addition of tungsten were discovered by Muschet in 1868, who has not been sufficiently credited with his share in making the Bessemer process a practical success, and later this alloy was investigated and improved by Maunsel White and Taylor, of Philadelphia. The latter showed that the addition of tungsten to steel has the following effect: That after the steel has been quenched at a very high temperature near its melting point it can be raised to a much higher temperature than is possible with ordinary carbon tool steel, without losing its hardness and power of cutting metal. In other words, it holds the carbon more tenaciously in the hardened state, and hence tungsten steel tools, even when red hot, can cut ordinary mild steel. It has revolutionised the design of machine tools and has increased the output on heavy munition work by 100 per cent., and in ordinary engineering by 50 per cent.

The alloys of steel and manganese with which Sir Robert Hadfield's name is associated have proved of utility in immensely increasing the durability of railway and tramway points and crossings, and for the hard teeth of machinery for the crushing of stone and other materials,

and, in fact, for any purposes where great hardness and strength are essential.

Investigation of Gaseous Explosions.—Brief reference must also be made—and it will be gratifying to do so—to the important work of one of the Committees of the British Association appointed in 1908, under the chairmanship of the late Sir William Preece, for the investigation of gaseous explosions, with special reference to temperature. The investigations of the Committee are contained in seven yearly reports up to 1914. Of the very important work of the Committee I wish to refer to one investigation in particular, which has proved to be a guiding star to the designers and manufacturers of internal combustion engines in this country. The members of the Committee more directly associated with this particular investigation were Sir Dugald Clerk, Professor Callendar, and the late Professor Bertram Hopkinson.

The investigation showed that the intensity of the heat radiated by the incandescent gases to the walls of the cylinder of a gas engine increases with the size of the cylinder, the actual rate of this increase being approximately proportional to the square root of the depth of the radiating incandescent gas; the intensity was also shown to increase rapidly with the richness of the gas. It suffices now to say that the heat in a large cylinder with a rich explosive mixture is so intense that the metal eventually cracks. The investigation shows why this occurs, and by doing so has saved enormous sums to the makers of gas and oil engines in this country, and has led them to avoid the large cylinder, so common in Germany before the war, in favour of a multiplicity of smaller cylinders.

Science and the War.

In coming to this section of my Address I am reminded that in the course of his Presidential Address to Section G, in 1858, Lord Rosse said: 'Another object of the Mechanical Section of the Association has been effected—the importance of engineering science in the service of the State has been brought more prominently forward. There seems, however, something still wanting. Science may yet do more for the Navy and Army if more called upon.'

Comparatively recently, too, Lord French remarked: 'We have failed during the past to read accurately the lessons as regards the fighting of the future which modern science and invention should have taught us.'

In view of the eminent services which scientists have rendered during the war, I think that we may be justified in regarding the requirement stated by Lord Rosse as having at last been satisfied, and also in believing that such a criticism as Lord French rightly uttered will not be levelled against the country in the future.

Though British men of Science had not formerly been adequately recognised in relation to war and the safety of their country, yet at the call of the sailors and the soldiers they whole-heartedly, and with intense zeal, devoted themselves to repair the negligence of the past, and to apply their unrivalled powers and skill to encounter and overcome the long-standing machinations of the enemy. They worked in close collaboration with the men of Science of the Allied Nations, and eventually produced better war material, chemicals, and apparatus of all kinds for vanquishing the enemy and the saving of our own men than had been devised by the enemy during many years of preparation planned on the basis of a total disregard of treaties and the conventions of war.

Four years is too short a time for much scientific invention to blossom to useful maturity, even under the forced exigencies of war and Government control. It must be remembered that in the past the great majority of new discoveries and inventions of merit have taken many years—sometimes generations—to bring them into general use. It must also be mentioned that in some instances discoveries and inventions are attributable to the general advance in Science and the Arts which has brought within the region of practical politics an attack on some particular problem. So the work of the scientists during the war has perforce been directed more to the application of known principles, trade knowledge, and properties of matter to the waging of war, than to the making of new and laborious discoveries; though, in effecting such applications, inventions of a high order have been achieved, some of which promise to be of great usefulness in time of peace.

The advance of Science and the Arts in the last century had, however, wrought a great change in the implements of war. The steam engine, the internal combustion engine, electricity, and the advances in metallurgy and chemistry had led to the building up of immense industries which, when diverted from their normal uses, have produced unprecedented quantities of war material for the purposes of the enormous armies, and also for the greatest Navy which the world has ever seen.

The destructive energy in the field and afloat has multiplied many hundredfold since the time of the Napoleonic wars; both before and during the war the size of guns and the efficiency of explosives and shell increased immensely, and many new implements of destruction were added. Modern Science and Engineering enabled armies unprecedented in size, efficiency and equipment to be drawn from all parts of the world and to be concentrated rapidly in the fighting line.

To build up the stupendous fighting organisation, ships have been taken from their normal trade routes, locomotives and material from the home railways, the normal manufactures of the country have been

largely diverted to munitions of war; the home railways, tramways, roads, buildings and constructions, and material of all kinds have been allowed to depreciate. The amount of depreciation in roads and railways alone has been estimated at 400 millions per annum at present prices. Upon the community at home a very great and abnormal strain has been thrown, notwithstanding the increased output per head of the workers derived from modern methods and improved machinery. In short, we have seen for the first time in history nearly the whole populations of the principal contending nations enlisted in intense personal and collective effort in the contest, resulting in unprecedented loss of life and destruction of capital.

A few figures will assist us to realise the great difference between this war and all preceding wars. At Waterloo, in 1815, 9,044 artillery rounds were fired, having a total weight of 37·3 tons, while on one day during the last offensive in France, on the British Front alone, 943,837 artillery rounds were fired, weighing 18,080 tons—over 100 times the number of rounds, and nearly 540 times the weight of projectiles. Again, in the whole of the South African War, 273,000 artillery rounds were fired, weighing approximately 2,800 tons; while during the whole war in France, on the British Front alone, over 170 million artillery rounds were fired, weighing nearly 3½ million tons—622 times the number of rounds, and about 1,250 times the weight of projectiles.

However great these figures in connection with modern land artillery may be, they become almost insignificant when compared with those in respect of a modern naval battle squadron. The *Queen Elizabeth* when firing all her guns discharges 18 tons of metal and develops 1,870,000 foot-tons of energy. She is capable of repeating this discharge once every minute, and when doing so develops by her guns an average of 127,000 effective horse-power, or more than one-and-a-half times the power of her propelling machinery; and this energy is five times greater than the maximum average energy developed on the Western Front by British guns. Furthermore, if all her guns were fired simultaneously, they would for the instant be developing energy at the rate of 13,132,000 horse-power. From these figures we can form some conception of the vast destructive energy developed in a modern naval battle.

Engineering and the War.

With regard to the many important engineering developments made during the war, several papers by authorities are announced in the syllabus of papers constituting the sectional proceedings of this year's Meeting. Among them are 'Tanks,' by Sir Eustace d'Eyncourt; 'Scientific Progress of Aviation during the War,' by Dr. Bairstow; 'Airships,' by Lieut.-Col. Cave-Brown-Cave; 'Directional Wireless, with Special

Reference to Aircraft,' by Capt. Robinson; 'Wireless in Aircraft,' by Major Erskine Murray; 'Wireless Telegraphy during the First Three Years of the War,' by Major Vincent Smith; 'Submarine Mining,' by Com. Gwynne; 'Emergency Bridge Construction,' by Prof. Ingles; and 'The Paravane,' by Com. Burney. Accordingly, it is quite unnecessary here to particularise further except in the few following instances:—

Sound-ranging and Listening Devices.—Probably the most interesting development during the war has been the extensive application of sound-listening devices for detecting and localising the enemy. The Indian hunter puts his ear to the ground to listen for the sound of the footsteps of his enemy. So in modern warfare science has placed in the hands of the sailor and soldier elaborate instruments to aid the ear in the detection of noises transmitted through earth, water, air, or ether, and also in some cases to record these sounds graphically or photographically, so that their character and the time of their occurrence may be tabulated.

The sound-ranging apparatus developed by Professor Bragg and his son, by which the position of an enemy gun can be determined from electrically recorded times at which the sound wave from the gun passes over a number of receiving stations, has enabled our artillery to concentrate their fire on the enemy's guns, and often to destroy them.

The French began experimenting in September 1914 with methods of locating enemy guns by sound. The English section began work in October 1915, adopting the French methods in the first instance. By the end of 1916 the whole Front was covered, and sound-ranging began to play an important part in the location of enemy batteries. During 1917 locations by sound-ranging reached about 30,000 for the whole army, this number being greater than that given by any other means of location. A single good set of observations could be relied upon to give the position of an enemy gun to about 50 yards at 7,000 yards range. It could also be carried on during considerable artillery activity.

The apparatus for localising noises transmitted through the ground has been much used for the detection of enemy mining and countermining operations. Acoustic tubes, microphones, and amplifying valves have been employed to increase the volume of very faint noises.

For many years before the war the Bell Submarine Signalling Company, of which Sir William White was one of the early directors, used submerged microphones for detecting sound transmitted through the water, and a submerged bell for sending signals to distances up to one mile. With this apparatus passing ships could be heard at a distance of nearly a mile when the sea was calm and the listening vessel stationary.

Of all the physical disturbances emitted or produced by a moving submarine, those most easily detected, and at the greatest distance, are the pressure waves set up in the water by vibrations produced by the vessel and her machinery. A great variety of instruments have been devised during the war for detecting these noises, depending on microphones and magnetophones of exceedingly high sensitivity. Among them may be particularly mentioned the hydrophones devised by Captain Ryan and Professor Bragg, being adaptations of the telephone transmitter to work in water, instead of air. These instruments, when mounted so as to rotate, are directional, being insensitive to sound waves whose front is perpendicular to the plane of the diaphragm, and giving the loudest sound when the diaphragm is parallel to the wave front.

Another preferable method for determining direction is to use two hydrophones coupled to two receivers, one held to each ear. This is called the biaural method, and enables the listener to recognise the direction from which the sound emanates.

When the vessel is in motion or the sea is rough the water noises from the dragging of the instrument through the water and from the waves striking the ship drown the noises from the enemy vessel, and under such conditions the instruments are useless. The assistance of eminent biologists was of invaluable help at this juncture. Experiments were made with sea-lions by Sir Richard Paget, who found that they have directional hearing under water up to speeds of six knots. Also Professor Keith explained the construction of the hearing organs of the whale, the ear proper being a capillary tube, too small to be capable of performing any useful function in transmitting sound to the relatively large aural organs, which are deep set in the head. The whale therefore hears by means of the sound waves transmitted through the substance of the head. It was further seen that the organs of hearing of the whale to some degree resembled the hydrophone.

The course now became clear. Hollow towing bodies in the form of fish or porpoises were made of celluloid, varnished canvas, or very thin metal, and the hydrophone suitably fixed in the centre of the head. The body is filled with water, and the cable towing the fish contains the insulated leads to the observer on board the vessel. When towed at some distance behind the chasing ship disturbing noises are small, and enemy noises can be heard up to speeds of 14 knots, and at considerable distances. Thermionic amplifying valves have been extensively used, and have added much to the sensitiveness of the hydrophone in its many forms.

After the loss of the *Titanic* by collision with an iceberg, Lewis Richardson was granted two patents in 1912 for the detection of above-water objects by their echo in the air, and underwater objects by the echo transmitted through the water. The principles governing the

production and the concentration of beams of sound are described in the specification, and he recommends frequencies ranging from 4,786 to 100,000 complete vibrations per second, and also suggests that the rate of approach or recession from the object may be determined from the difference in the pitch of the echo from the pitch of the blast sent out. Hiram Maxim also suggested similar apparatus a little later.

The echo method of detection was not, however, practically developed until French and English scientists, with whom was associated Professor Langevin, of the College de France, realising its importance for submarine detection, brought the apparatus to a high degree of perfection and utility shortly before the Armistice. Now, with beams of high-frequency sound waves, it is possible to sweep the seas for the detection of any submerged object, such as icebergs, submarines, surface vessels, and rocks; they may also be used to make soundings. It enables a chasing ship to pick up and close in on a submarine situated more than a mile away.

The successful development of sound-ranging apparatus on land led to the suggestion by Professor Bragg that a modified form could be used to locate under-water explosions. It has been found that the shock of an explosion can be detected hundreds of miles from its source by means of a submerged hydrophone, and that the time of the arrival of the sound wave can be recorded with great precision. At the end of the war the sound-ranging stations were being used for the detection of positions at sea, required for strategical purposes. The same stations are now being used extensively for the determination of such positions at sea as light-vessels, buoys which indicate channels, and obstructions such as sunken ships. By this means ships steaming in fog can be given their positions with accuracy for ranges up to 500 miles.

Among the many other important technical systems and devices brought out during the war which will find useful application under peace conditions as aids to navigation I may mention directional wireless, by which ships and aircraft can be given their positions and directed, and on this subject we are to have a paper in Section G.

Leader gear, first used by the Germans to direct their ships through their minefields, and subsequently used by the Allies, consists of an insulated cable laid on the bottom of the sea, earthed at the further end, and through which an alternating current is passed. By means of delicate devices installed on a ship, she is able to follow the cable at any speed with as much precision as a railless electric 'bus can follow its trolley wire. Cables up to 50 miles long have been used, and this device promises to be invaluable to ships navigating narrow and tortuous channels and entering or leaving harbours in a fog.

Aircraft.—It may be justly said that the development in aircraft design and manufacture is one of the astonishing engineering

feats of the war. In August 1914 the British Air Services possessed a total of 272 machines, whereas in October 1918, just prior to the Armistice, the Royal Air Force possessed over 22,000 effective machines. During the first twelve months of the war the average monthly delivery of aeroplanes to our Flying Service was fifty, while during the last twelve months of the war the average deliveries were 2,700 per month. So far as aero-engines are concerned, our position in 1914 was by no means satisfactory. We depended for a large proportion of our supplies on other countries. In the Aerial Derby of 1913, of the eleven machines that started, not one had a British engine. By the end of the war, however, British aero-engines had gained the foremost place in design and manufacture, and were well up to requirements as regards supply. The total horse-power produced in the last twelve months of the war approximated to eight millions of brake horse-power, a figure quite comparable with the total horse-power of the marine engine output of the country.[1]

Much might be written on the progress in aircraft, but the subject will be treated at length in the sectional papers. In view of the recent trans-Atlantic flights, however, I feel that it may be opportune to make the following observations on the comparative utility of aeroplanes and airships for commercial purposes. In the case of the aeroplane, the weight per horse-power increases with the size, other things being equal. This increase, however, is met to some extent by a multiplicity of engines, though in the fusilage the increase remains.

On the other hand, with the airship the advantage increases with the size, as in all ships. The tractive effort per ton of displacement diminishes in inverse proportion to the dimensions, other things, including the speed, being the same. Thus, an airship of 750 feet length and 60 tons displacement may require a tractive force of 5 per cent., or 3 tons, at 60 miles per hour; and one of 1,500 feet in length and $8 \times 60 = 480$ tons displacement would only require $2\frac{1}{2}$ per cent. $\times 480 = 12$ tons at the same speed, and would carry fuel for double the distance.

With the same proportion of weight of hull to displacement, the larger airship would stand double the wind pressure, and would weather storms of greater violence and hailstones of greater size. It would be more durable, the proportional upkeep would be less, and the proportional loss of gas considerably less. In other words, it would lose a less proportion of its buoyancy per day. It is a development in which success depends upon the project being well thought out and the job being thoroughly well done. The equipment of the airsheds with numerous electric haulage winches, and all other appliances to make

[1] See Lord Weir's Paper read at the Victory Meeting of the North-East Coast Institution of Engineers and Shipbuilders, July 1919.

egress and ingress to the sheds safe from danger and accident, must be ample and efficient.

The airship appears to have a great future for special commerce where time is a dominant factor and the demand is sufficient to justify a large airship. It has also a great field in the opening up of new countries where other means of communication are difficult. The only limitation to size will be the cost of the airship and its sheds, just as in steam vessels it is the cost of the vessels and the cost of deepening the harbours that limit the size of Atlantic liners.

Such developments generally take place slowly, otherwise failures occur—as in the case of the *Great Eastern*—and it may be many years before the airship is increased from the present maximum of 750 feet to 1,500 feet with success, but it will assuredly come. If, however, the development is subsidised or assisted by Government, incidental failures may be faced with equanimity and very rapid development accomplished.[2] In peace time the seaplane, aeroplane, and airship will most certainly have their uses. But, except for special services of high utility, it is questionable whether they will play more than a minor part as compared with the steamship, railway, and motor transport.

Electricity.—The supply and use of electricity has developed rapidly in recent years. For lighting it is the rival of gas, though each has its advantages. As a means of transmitting power over long distances it has no rival, and its efficiency is so high that when generated on a large scale and distributed over large areas it is a cheap and reliable source of power for working factories, tramways, suburban railways, and innumerable other purposes, including metallurgical and chemical processes. It is rapidly superseding locally generated steam-power, and is a rival to the small and moderate-sized gas and oil engines. It has made practicable the use of water-power through the generation of electricity in bulk at the natural falls, from which the power is transmitted to the consumers, sometimes at great distances.

Fifteen years ago electricity was generated chiefly by large reciprocating steam engines, direct coupled to dynamos or alternators, but of late years steam turbines have in most instances replaced them, and are now exclusively used in large generating stations, because of their smaller cost and greater economy in fuel. The size of the turbines may vary from a few thousand horse-power up to about 50,000 horse-power. At the end of last year the central electric stations in the United Kingdom contained plant aggregating $2\frac{3}{4}$ million kilowatts, 79 per cent. of which was driven by steam turbines.

[2] The literature on this subject includes an article which appeared in *Engineering* on January 3, 1919.

Much discussion has taken place as to the most economical size of generating stations, their number, the size of the generating units, and the size of the area to be supplied. On the one hand, a comparatively small number of very large or super-stations, instead of a large number of moderate-sized stations dotted over the area, results in a small decrease in the cost of production of the electricity, because in the super-stations larger and slightly more economical engines are employed, while the larger stations permit of higher organisation and more elaborate labour-saving appliances. Further, if in the future the recovery of the by-products of coal should become a practical realisation as part of the process in the manufacture of the electric current, the larger super-stations present greater facilities than the smaller stations. On the other hand, super-stations involve the transmission of the electricity over greater distances, and consequently greater capital expenditure and cost of maintenance of mains and transmission apparatus, and greater electrical transmission losses, while the larger generating unit takes longer to overhaul or repair, and consequently a larger percentage of spare plant is necessary.

The greatest element in reducing the cost of electricity is the provision of a good load factor; in other words, the utilisation of the generating plant and mains to the greatest extent during the twenty-four hours of each day throughout the year. This is a far more important consideration than the size of the station, and it is secured to the best advantage in most cases by a widespread network of mains, supplying a diversity of consumers and uses, each requiring current at different times of the day. The total load of each station being thus an average of the individual loads of a number of consumers is, in general, far less fluctuating than in the case of small generating and distributing systems, which supply principally one class of consumer, a state of affairs that exists in London, for instance, at the present time. It is true that there may be exceptional cases, such as at Kilmarnock, where a good load factor may be found in a small area, but in this case the consumers are chiefly mills, which require current for many hours daily.

There is no golden rule to secure cheap electricity. The most favourable size, locality, and number of generating stations in each area can only be arrived at by a close study of the local conditions, but there is no doubt that, generally speaking, to secure cheap electricity a widespread network of mains is in most cases a very important, if not an essential, factor.

The electrification of tramways and suburban railways has been an undoubted success where the volume of traffic has justified a frequent service, and it has been remarkable that where suburban lines have been worked by frequent and fast electrical trains there has resulted

a great growth of passenger traffic. The electrification of main line railways would no doubt result in a saving of coal; at the same time, the economical success would largely depend on the broader question as to whether the volume of the traffic would suffice to pay the working expenses, and provide a satisfactory return on the capital.

Municipal and company generating stations have been nearly doubled in capacity during the war to meet the demand from munition works, steel works, chemical works, and for many other purposes. The provision of this increased supply was an enormous help in the production of adequate munitions. At the commencement of the war there were few steel electric furnaces in the country; at the end of last year 117 were at work, producing 20,000 tons of steel per month, consisting chiefly of high-grade ferro alloys used in munitions.

The Future.

The nations who have exerted the most influence in the war have been those who have developed to the greatest extent their resources, their manufactures, and their commerce. As in the war, so in the civilisation of mankind. But, viewing the present trend of developments in harnessing water-power and using up the fuel resources of the world for the use and convenience of man, one cannot but realise that, failing new and unexpected discoveries in science, such as the harnessing of the latent molecular and atomic energy in matter, as foreshadowed by Clerk Maxwell, Kelvin, Rutherford, and others, the great position of England cannot be maintained for an indefinite period. At some time more or less remote—long before the exhaustion of our coal—the population will gradually migrate to those countries where the natural sources of energy are the most abundant.

Water-power and Coal.—The amount of available water-power in the British Isles is very small as compared with the total in other countries. According to the latest estimates, the total in the British Isles is under $1\frac{1}{2}$ million horse-power, whereas Canada alone possesses over 20 millions, of which over 2 millions have already been harnessed. In the rest of the British Empire there are upwards of 30 millions and in the remainder of the world at least 150 millions, so that England herself possesses less than 1 per cent. of the water-power of the world. Further, it has been estimated that she only possesses $2\frac{1}{2}$ per cent. of the whole coal of the world. To this question I would wish to direct our attention for a few minutes.

I have said that England owes her modern greatness to the early development of her coal. Upon it she must continue to depend almost exclusively for her heat and source of power, including that required for propelling her vast mercantile marine. Nevertheless, she is using up her resources in coal much more rapidly than most other countries are

consuming theirs, and long before any near approach to exhaustion is reached her richer seams will have become impoverished, and the cost of mining so much increased that, given cheap transport, it might pay her better to import coal from richer fields of almost limitless extent belonging to foreign countries, and workable at a much lower cost than her own.

Let us endeavour to arrive at some approximate estimate of the economic value of the principal sources of power. The present average value of the royalties on coal in England is about 6*d*. per ton, but to this must be added the profit derived from mining operations after paying royalties and providing for interest on the capital expended and for its redemption as wasting capital. After consultation with several leading experts in these matters, I have come to the conclusion that about 1*s*. per ton represents the pre-war market value of coal in the seams in England.

It must, however, be remembered that, in addition, coal has a considerable value as a national asset, for on it depends the prosperity of the great industrial interests of the country, which contribute a large portion of the wealth and revenue. From this point of view the present value of unmined coal seems not to have been sufficiently appreciated in the past, and that in the future it should be better appraised at its true value to the nation.

This question may be viewed from another aspect by making a comparison of the cost of producing a given amount of electrical power from coal and from water-power. Assuming that one horse-power of electrical energy maintained for one year had a pre-war value of 5*l*., and that it requires about eight tons of average coal to produce it, we arrive at the price of 6*s*. 3*d*. per ton—*i.e.*, crediting the coal with half the cost. The capital required to mine eight tons of coal a year in England is difficult to estimate, but it may be taken approximately to be 5*l*., and the capital for plant and machinery to convert it into electricity at 10*l*., making a total of 15*l*. In the case of water-power the average capital cost on the above basis is 40*l*., including water rights (though in exceptionally favoured districts much lower costs are recorded).

From these figures it appears that the average capital required to produce electrical power from coal is less than half the amount that is required in the case of water-power. The running costs, however, in connection with water-power are much less than those in respect of coal. Another interesting consideration is that the cost of harnessing all the water-power of the world would be about 8,000 millions, or equal to the cost of the war to England.

Dowling has estimated the total coal of the world as over seven million million tons, and whether we appraise it at 1*s*. or more per ton

its present and prospective value is prodigious. For instance, at 6*s*. 3*d*. per ton it amounts to nearly one hundred times the cost of the war to all the belligerents.

In some foreign countries the capital costs of mining are far below the figures I have taken, and, as coal is transportable long distances and, generally speaking, electricity is not so at present, therefore it seems probable that capital will in the immediate future flow in increasing quantity to mining operations in foreign countries rather than to the development of, at any rate the more difficult and costly, water-power schemes. When, however, capital becomes more plentiful the lower running costs of water-power will prevail, with the result that water-power will then be rapidly developed.

As to the possible new sources of power, I have already mentioned molecular energy, but there is another alternative which appears to merit attention.

Bore Hole.—In my address to Section B in 1904 I discussed the question of sinking a shaft to a depth of twelve miles, which is about ten times the depth of any shaft in existence. The estimated cost was 5,000,000*l*., and the time required about eighty-five years.

The method of cooling the air-locks to limit the barometric pressure on the miners and other precautions were described, and the project appeared feasible. One essential factor has, however, been queried by some persons: Would the rock at the great depth crush in and destroy the shaft? Subsequent to my address, I wrote a letter to *Nature*, suggesting that the question might be tested experimentally. Professor Frank D. Adams, of McGill University, Montreal, acting on the suggestion, has since carried out exhaustive experiments, published in the *Journal of Geology* for February 1912, showing that in limestone a depth of fifteen miles is probably practicable, and that in granite a depth of thirty miles might be reached.

Little is at present known of the earth's interior, except by inference from a study of its surface, upturned strata, shallow shafts, the velocity of transmission of seismic disturbances, its rigidity and specific gravity, and it seems reasonable to suggest that some attempt should be made to sink a shaft as deep as may be found practicable and at some locality selected by geologists as the most likely to afford useful information.

When we consider that the estimated cost of sinking a shaft to a depth of twelve miles, at present-day prices, is not much more than the cost of one day of the war to Great Britain alone, the expense seems trivial as compared with the possible knowledge that might be gained by an investigation into this unexplored region of the earth. It might, indeed, prove of inestimable value to Science, and also throw

additional light on the internal constitution of the earth in relation to minerals of high specific gravity.

In Italy, at Lardarello, bore holes have been sunk, which discharge large volumes of high-pressure steam, which is being utilised to generate about 10,000 horse-power by turbines. At Solfatara, near Naples, a similar project is on foot to supply power to the great works in the district. It seems, indeed, probable that in volcanic regions a very large amount of power may be, in the future, obtained directly or indirectly by boring into the earth, and that the whole subject merits the most careful consideration.

While on the subject of obtaining power, may I digress for a few moments and describe an interesting phenomenon of a somewhat converse nature—*viz.* that of intense pressure produced by moderate forces closing up cavities in water.

A Committee was appointed by the Admiralty in 1916 to investigate the cause of the rapid erosion of the propellers of some of the ships doing arduous duties. This was the first time that the problem had been systematically considered. The Committee found that the erosion was due to the intense blows struck upon the blades of the propellers by the nuclei of vacuous cavities closing up against them. Though the pressure bringing the water together was only that of the atmosphere, yet it was proved that at the nucleus 20,000 atmospheres might be produced.

The phenomenon may be described as being analagous to the well-known fact that nearly all the energy of the arm that swings it is concentrated in the tag of a whip. It was shown that when water flowed into a conical tube which had been evacuated a pressure of over 140 tons per square inch was recorded at the apex, which was capable of eroding brass, steel, and in time even the hardest steel. The phenomenon may occur under some conditions in rivers and waterfalls where the velocity exceeds 50 feet per second, and it is probably as great a source of erosion as by the washing down of boulders and pebbles. Then again, when waves beat on a rocky shore, under some conditions, intense hydraulic pressures will occur, quite sufficient of themselves to crush the rock and to open out narrow fissures into caves.

Research.—The whole question of the future resources of the Empire is, I venture to think, one which demands the serious attention of all scientists. It should be attacked in a comprehensive manner, and with that insistence which has been so notable in connection with the efforts of British investigators in the past. In such a task, some people might suggest, we need encouragement and assistance from the Government of the country. Surely we have it. As many here know, a great experimental step towards the practical realisation of Solomon's House as prefigured by Lord Bacon in the *New Atlantis* is being made by the

Government at the present time. The inception, constitution, and methods of procedure of the Department, which was constituted in 1915, were fully described by Sir Frank Heath in his paper to the Royal Society of Arts last February, and it was there stated by Lord Crewe that, so far as he knew, this was the only country in which a Government Department of Research existed.[3]

It is obvious that the work of a Department of this kind must be one of gradual development with small beginnings, in order that it may be sound and lasting. The work commenced by assisting a number of researches conducted by scientific and professional societies which were languishing as a result of the war, and grants were also made to the National Physical Laboratory and to the Central School of Pottery at Stoke-on-Trent. The grants for investigation and research for the year 1916-17 totalled 11,055*l.*, and for the present year are anticipated to be 93,570*l.* The total income of the National Physical Laboratory in 1913-14 was 43,713*l.*, and owing to the great enlargement of the Laboratory the total estimate of the Research Department for this service during the current year is 154,650*l.*

Another important part of the work of the Department has been to foster and to aid financially Associations of the trades for the purpose of research. Nine of these Associations are already at work; eight more are approved, and will probably be at work within the next two months; and another twelve are in the earlier stage of formation. There are also signs of great increase of research by individual factories. Whether this is due to the indirect influence of the Research Department or to a change in public opinion and a more general recognition of the importance of scientific industrial research it is difficult to say.

The possibility of the uncontrolled use on the part of a nation of the power which Science has placed within its reach is so great a menace to civilisation[4] that the ardent wish of all reasonable people is to possess some radical means of prevention through the establishment of some form of wide and powerful control. Has not Science forged the remedy, by making the world a smaller arena for the activities of civilisation, by reducing distance in terms of time? Alliances and unions, which have successfully controlled and stimulated republics of heterogeneous races during the last century, will therefore have become possible on a wider and grander scale, thus uniting all civilised nations in a great League to maintain order, security, and freedom for every

[3] The Italian Government are now establishing a National Council for Research, and a Bill is before the French Chamber for the establishment of a National Office of Scientific, Industrial, and Agricultural Research and Inventions.

[4] For instance, it might some day be discovered how to liberate instantaneously the energy in radium, and radium contains $2\frac{1}{2}$ million times the energy of the same weight of T.N.T.

individual and for every State and nation liberty to devote their energies to the controlling of the great forces of Nature for the use and convenience of man, instead of applying them to the killing of each other.

Many of us remember the President's Banner at the Manchester Meeting in 1915, where Science is allegorically represented by a sorrowful figure covering her eyes from the sight of the guns in the foreground. This year Science is represented in her more joyful mien, encouraging the arts and industries. It is to be sincerely hoped that the future will justify our present optimism.

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SECTION A: BOURNEMOUTH, 1919.

ADDRESS

TO THE

MATHEMATICAL AND PHYSICAL SCIENCE SECTION

BY

PROFESSOR A. GRAY, M.A., LL.D., F.R.S.,

PRESIDENT OF THE SECTION.

I HAVE devoted some little time to the perusal of the Addresses of my predecessors in this Chair. These have a wide range. They include valuable philosophical discussions of the nature of scientific knowledge and expositions of scientific method, as well as highly instructive *résumés* and appreciations of the progress of mathematics and physics. But as this is the first meeting of the British Association since the conclusion of peace I have decided to disregard in the main these precedents, and to endeavour to point out, in the first place, some of the lessons which the war has, or ought to have, taught our country and those who direct its policy, and in particular ourselves, whose vocation it is to cultivate and to teach mathematical and physical science.

Before proceeding with this task I must refer to the loss which physical science and the British Association have suffered this year through the deaths of Professor Carey Foster and Lord Rayleigh. Both of these great physicists were regular in attendance at the meetings of the Association, and they will be greatly missed.

What Carey Foster was as a man of science, as a teacher, and as a friend of all students of physics, has been worthily set forth in the columns of *Nature*, with all the knowledge and affectionate reverence of one who was at once his pupil and his fellow-worker at University College. To that eloquent tribute I will not, though I knew Carey Foster well, venture to add a word.

It is not for me to appraise the work of Lord Rayleigh. But I may say that for something like half a century his name has stood not only for things that are great in physical discovery, but for sanity of judgment, and clarity, elegance, and soundness of treatment of outstanding and difficult problems of mathematical physics. His researches, too, in experimental science have been fruitful in results of the utmost importance in chemistry as well as in physics. With him there was no shirking of the toil of monotonous and systematic observation from day to day, in the pursuit of the greatest attainable accuracy: take, for example, his work on electrical units. But his influence on applied mathematics has also been enormous, and places him for all time in the foremost rank of the great physical mathematicians, at the head of which stands Isaac Newton. One has only to read his Treatise on the Theory of Sound, and his papers on Optics and Wave Theory, to find some of the most striking examples in all scientific literature of the working of a mind not only of the first order of originality, but imbued with a feeling for symmetry of form and clearness of exposition.

Lord Rayleigh's genius was, it seems to me, essentially intuitive and practical. Though he was not given to any striving after the utmost rigidity of formal proof, which, as he himself remarked, might not be more but less demonstrative to the physicist than physical reasons, no man made fewer mistakes. He is gone, but he has left an inspiring example to his order and to his countrymen of a long life consecrated to the object for which the Royal

Society, of which he had been the honoured President, was founded, the furtherance of Natural Knowledge.

The part which physical science has played in the conduct of the war on our side has been an important one, but it has by no means been so decisive as it might and ought to have been. And here lie the lessons which I think we can draw from the terrible events which have taken place. Some few people, mostly hostile to or jealous of science, whose vision of facts and tendencies seems to me to be hopelessly obscured by prejudice, would try to impose on the advance of natural knowledge and the supposed increased influence of scientific ideas on the minds of men, or, perhaps more precisely, on the diminution of the study of the so-called humanities, the sole or the main responsibility for the outbreak of war. It seems to me that a good many people allow themselves to be misled by a name. The name *Humanity* is given in the Scottish Universities to the department of the Latin language and literature, and in a wider usage the study of Latin and Greek is referred to as that of *Litteræ Humaniores*. But I am not aware that there is any more humanity, in the common acceptation of the term, about these studies than there is in many others. And experience has shown that the assertion that these studies have a special refining influence, while the pursuit of science has a brutalising tendency, is based on ignorance and partiality. The truth is that the man who knows nothing of science, and he who has neglected the study of letters, are both imperfectly educated.

Well, the accusation I refer to may be dismissed without argument. This is certainly not the time nor the place for a discussion of the causes of the war, or of the ethics of the extraordinary methods introduced into warfare by our enemies. But one thing I will say in this connection. Even poison gas is innocent in itself, and it occurs as a product in perfectly indispensable and eminently useful chemical processes. The extraordinary potency of scientific knowledge for the good of civilised mankind is frequently conjoined with a potency for evil; but the responsibility for an inhuman use of it does not lie with the scientific investigator. The guilt lies at the door of the High Commando, of the high and mighty persons, themselves in feeling and temper utterly unscientific, who approved and directed the employment of methods of attack which destroyed the wounded and helpless, and wrecked for ever the health of many of those who emerged alive from the inferno.

As regards the help which British science was able to render in the defence against the German attack and the operations which followed when the fortune of war changed so dramatically, and the enemy was driven back towards the chain of fastnesses from behind which he originally emerged, one or two obvious reflections must have occurred to everyone. In one form or another these have been referred to by various writers, but I may recall one or two of them, for as a people we are incorrigibly forgetful and appear to be almost incapable of profiting from experience, which, according to the Latin proverb, teaches even fools.

Nearly twenty years ago the urgent necessity for the reorganisation of our military machinery had been, in the view of civilians at least, who had to bear the cost of the war in South Africa, demonstrated *ad nauseam*, but nothing of real importance in the way of reforming the War Office seems to have been done. The shocks we had received were forgotten, and soon the nation returned to its insular complacency, the old party cries resounded in the market-place, the hacks of party politics again resumed their occupation of camouflage and hoodwinking, and the country drifted on towards its fate.

All this time an enormously powerful war machine was being built up on the Continent, and its different parts tested so far as that could be done without actual warfare. The real object of these preparations was carefully veiled by an appearance of frankness and professions of goodwill, though it was revealed every now and then by the indiscretions of the German military caste. To these indications and to others the country, ostrich-like, covered its eyes.

Now it is often alleged that men engrossed in the pursuit of science are unbusinesslike, but I think that, if there had been any truly scientific element in the *personnel* of the Government (there never is by any chance), attention would have been directed at a much earlier period to our hopeless state of

unpreparedness for the storm which was gradually gathering up against us on the other side of the German Ocean. In discussions of our unpreparedness the emphasis has been placed on our lack of arms and munitions. But important as these are, the entire absence of a scientific organisation to guide us in the exigencies of a defensive war with the most scientific and most military nation of Europe was even more serious.

It is this deficiency in our organisation, a deficiency the avoidance of which would have had no provocative effect whatever, which concerns us here very specially. It is, moreover, a deficiency which, in spite of the lessons they have received, has, I fear, not yet been brought home to our military chiefs. When war broke out nothing had been done to ensure the utilisation for special service in the multitude of scientific operations, which war as carried on by the German armies involved, of the great number of well-trained young scientific men available in the country. The one single idea of our mobilisers was to send men to the trenches to kill Germans, and for this simple duty all except certain munition workers and men in the public services were summoned to the Army. Some modifications were made afterwards, but I am speaking of the failure of prevision at the outset. The need of men for special service, the inevitable expansion of the Navy for patrol and other purposes and the like, were, if they were thought of at all, put aside, without regard to the difficulties which would inevitably arise if these matters were delayed. Even how the new soldiers were to be trained, almost without rifles or machine guns, to meet the Germans in the field nobody knew. And I for one believe that but for the vigour and energy of Lord Kitchener, and the almost too late expression of conviction of our danger, and consequent action, by one outstanding politician, all would have been lost. We worried through, but at a loss of life and treasure from which it will take us long to recover, and which I could wish seemed to weigh more heavily on the minds and consciences of politicians.

The Germans, I believe, had a complete record not only of all their men fitted only for the rank and file, but also of all who had been trained to observe and measure. For the use of even the very simplest apparatus of observation a certain expertness in reading graduated scales, and generally a certain amount of trained intelligence is required. For this the laboratories of Germany amply provided, and the provision had its place in the enemy's mobilisation. Our people apparently did not even know that such a need existed or might arise.

In a letter which I sent to the Council of the Royal Society at the end of 1915 I ventured to propose that the Royal Society might set on foot an organisation of some such character as the following :—First, a Central Committee should be established, in some degree representative of the different centres of scientific teaching and work in pure and applied science. Then this Committee should nominate representatives at each centre, at least one at each University or College, and one at the headquarters of each local society, such, for example, as the Institution of Engineers and Shipbuilders of Scotland and the similar Society which represents the North-East of England, and has its offices at Newcastle-on-Tyne. This arrangement, it was hoped, would enable the Central Committee to obtain readily information as to what men were available, and would therefore do something to bring the schools of science, and all the great workshops and laboratories of applied science, into co-operation. Thus could be formed at once a list of men available for particular posts, for the task of solving the problems that were certain to arise from day to day, and for the special corps which it was soon, if dimly, perceived were a necessity. Some such linking up of London with the provinces is really indispensable. The districts of, for example, the Tyne and the Clyde are too much ignored in almost all Government action of a general kind.

My letter was printed and sent out to some prominent men by whom its proposals were highly approved. A Conference on its subject was held in London, and two special Committees were appointed. I was a member of one of these, the principal duty of which was to provide scientific men for special service. It included representatives of the various great departments, actively engaged in the conduct of the war. For some reason or other, which I never learned, the Committee after a week or two ceased to be called, and, I believe, that little was done in comparison with what might have been

accomplished. It was certainly not because such a committee would not work. Everybody was most willing, with proper notice, to attend such meetings as were involved, and to take any amount of personal trouble; moreover, the scheme was such as to provide that there should always be a nucleus of members in London to consult and act in any emergency.

I may briefly refer to one or two examples of the chaos which prevailed and the attempts that were made to cope with it. Very soon after the formation of the first Kitchener Army the organisation of the different corps apparently became a source of anxiety to the War Office. It began to be seen that officers in sufficient numbers could not possibly be obtained by the usual channels, so the expedient (a poor one by itself) was hit upon of placing the nominations to commissions in one at least of the two great scientific corps of the Army—the Royal Engineers—in the hands of the presidents of certain technical Institutions which have their headquarters in London. These gentlemen, with the help of the official secretaries, no doubt did the best they could, but a very regrettable, though perfectly natural, amount of strong feeling was evoked among the young scientifically educated men in the provinces, who were keenly anxious to join this corps. The Engineers, I may hardly say, is no refuge for men who are in the least concerned about their personal safety, for the percentage of casualties among Engineers on active service was notably higher than in the regiments of the line. Over and over again young engineers came to me, and complained that under the arrangements made they had no chance of obtaining commissions, or of qualifying as cadets, and begged me to write to the authorities. Of course, young graduate engineers do not as a rule join Societies such as the Institutions of Civil, Mechanical, or Electrical Engineers, until they have made their way to some little extent, and begun to earn a little money.

The procedure I have indicated had in time to be relaxed, but such a Central Committee as I suggested, with antennæ stretching out to the educational and technical centres of the country would, I am sure, have recruited the Engineers quickly with the best possible material for officers to be found in the country, to the satisfaction of all concerned. It may be said that full information regarding every man in the country was in the hands of the authorities. In a sense this was true; the information existed in millions of returns, and thousands of pigeon-holes, but no attempt was made, or could be made, by office staffs in London, enormous as these quickly became, to digest and utilise it.

A large number of engineers and physicists and many others of mechanical skill and aptitudes found congenial occupation in the Royal Naval Air Service and the Royal Flying Corps; but even there, where things could be better done, since a new force had to be brought into existence, arrangements were to a considerable extent haphazard and ill thought out. Excellent self-sacrificing service was rendered by many, who risked and gave their lives, and of what was done we may well be proud. But from a scientific point of view there is room for great improvement. The, as I think, hasty and ill-considered amalgamation of these two branches of the Air Service, in which naval traditions were sacrified to those of the War Office, which deserved no such deference, will certainly have to be undone in the near future, or very greatly transformed. To anyone who considers the possibilities and probabilities of warfare in the future, it appears clear that this country will have to depend more and more upon its Navy, and that an Air Service Corps will be the companion of every division of our Fleet, with landings on the warships. Thus a new and highly scientific service, which will have to be to a great extent naval, will be brought into existence.

Well, then, to return for a moment to my proposal to the Royal Society, why should the organisation which I suggested in 1915 not be established now? I wish all success to the League of Nations, but we shall prove ourselves even greater fools than we have been in the past if we do not use all possible means to prepare ourselves against eventualities. One attempt by our enemies outside our own borders to hold us to ransom has failed. Can we be so sure that no other attempt will ever be made, or that no *casus belli* between ourselves and another great nation will ever arise? This, I notice, is beginning to be assumed even in the midst of the welter of confusion and unrest that exists, and, among others, by just the very people who used to teach that the possibility of war was a great illusion.

The formation of a record of scientific graduates for special service ought not to be difficult. The material already in great measure exists. Each University and College has its roll of graduates or diploma holders, and with slightly more detailed entries these rolls would give the record. Each graduate of a University is kept track of through the necessity for keeping the electoral roll up to date, and it ought to be possible to devise a means of maintaining touch with the diploma holder. If each University or College were a local centre of the Central Committee, the making of the roll of graduates would be achieved at the different local headquarters, and would be a valuable supplement to the O.T.C. work now undertaken so willingly and done so well. The Government machinery which manages the O.T.C. movement might control the keeping of the register which I have suggested.

I turn now to another side of scientific work during the war. It was my lot to serve for nearly three years on the Inventions Panel of the Ministry of Munitions, and as the result of that experience I venture to make some observations on the utilisation of scientific knowledge and genius in the production of inventions useful for the public service. We had an enormous multitude of inventions to consider, and the Panel was divided into Committees for this purpose. For each invention or proposal a file or dossier was prepared and most carefully kept. There were also present at the meetings of the Panel very efficient officers representing different branches of the service. Everything received careful attention, and for the ability and fairness with which the initial examination was made by the corps of examiners, and the *précis* of the invention presented, I have great admiration. Much has been said about the inefficiency and the mistakes of various Government Departments during the war. The Ministry of Munitions Inventions Department was, so far as I could see, eminently well managed.

Many of the so-called inventions were not inventions at all. Some were not at all new; in other cases an idea only was mooted. Could so-and-so not be done? and so on, and the Department was supposed to be grateful for the idea, and to do the rest, besides rewarding the proposer. A favourite notion, which illustrates the diffusion of scientific knowledge among different classes of people, was that of taking a magnet—any magnet—up on an aeroplane, and using it to attract Zeppelins and other aircraft. Others suggested electro-magnets fed by machines which would have involved carrying into the air on an aeroplane a fully equipped power-house! Another favourite notion, inspired, no doubt, by a certain sensational type of article in the fiction magazines, was that of rays charged in some way with electricity, or some other mysterious agency, and therefore intensely destructive.

But there was a residuum of valuable inventions, which fully justified the existence of the Department. These were recommended for further consideration by the various departments of the services, or by General Headquarters. It by no means followed that all that came to this stage received careful further consideration. Everybody was very hard worked, and many were overdriven. And it was by no means certain that when important approved appliances were sent to G.H.Q. a thoroughly well-informed and capable officer would in all cases have the duty of explaining and showing their action. The absence of such an officer, I am sure, often resulted in delay and serious error, and, I fear, also in the rejection of what was in itself exceedingly good, but was not understood. People who knew nothing about the matter took charge, and ordered things to be done which brought disaster to the apparatus. I know of one very important machine which was ruined, with much resulting delay. A Brigadier or Major-General with a confidence born of blank ignorance ordered a motor generator to be put on town electric mains, and of course burnt it out.

Then, again, we were told that G.H.Q. did not want this or that, and here, as in all human affairs, mental inertia certainly played a considerable part. The willingness, however, of some departments to adopt at once a device captured from the enemy was pathetic. Often quite clumsy and relatively inferior contrivances were adopted in the midst of hesitation about our own. Anything German of this sort some people assumed must be good—a foolish idea, the result of want of confidence, often well founded I am afraid, in their own

judgment. It is legitimate to copy from the enemy, and in several important things we have not been slow to do so.

The delays that occurred were to some of us at home, who were anxiously dealing with all kinds of contrivances, exceedingly exasperating. Some were undoubtedly unavoidable, but others were, as I have indicated, far otherwise. Deficiency in scientific education was the cause. It is to enforce the need for such education that I refer to such matters at all. The "playing fields of Eton" are all very well. I for one do not scoff at what the old saying stands for, but scientific laboratories and good intelligent work in them are indispensable. A man who directs in whole or in part a great machine must know something of its structure and capabilities.

I feel bound to allude to another aspect of the inventions business which to my mind was very serious. In doing so, however, I wish it to be clearly understood that I am criticising a system and in no way here referring to particular individuals concerned in its administration. Various inventions which had passed satisfactorily the first examinations by responsible judges were submitted to technical departments at home to be subjected to practical tests. These inventions were, frequently, solutions proposed of problems on which technical officers, of the departments required to conduct the tests, had long been engaged. It was natural, indeed inevitable, that some of these officers should have come to regard the solving of these problems as their own special job, and so did not much welcome the coming of the outside inventor. Then, no doubt, they often felt that they were just on the point of arriving at a solution—a feeling that certainly could not facilitate the avoidance of delay. It was manifestly most unfair to ask them to judge the work of the outside inventor, or to place in their hands details of his proposals, for exactly the same reason which in civil life restrains a man from acting as a conjuror in a case in which he is personally interested. Nobody of good sense feels offended when attention is called to such a rule in practice.

Thus I have no hesitation in expressing the opinion that a testing board of practical, well-qualified physicists and other experts, with a properly qualified staff, should be formed for the purpose of carrying out all tests of inventions. No insuperable difficulty would, I believe, be experienced in forming such a board. It should be formed carefully, not by more or less casual nomination of one another by a few persons. Expert knowledge of a subject should be a necessary qualification; the so-called 'open mind' of the much-lauded but untrained practical man is not worth having. But on that board neither inside nor outside inventors of the same kind of appliances should have any place, though of course consultation with the author of an invention under test would be absolutely necessary. Also those actually carrying out the tests and those collating the results should not be men in any way in the employment of or under the supervision of inventors, whether 'outside' or 'inside.' It is imperative in the interests of the country that delay in such matters should be avoided, and that all such work should be done without fear or favour.

The value of University and College men trained in science has been thoroughly proved in the Artillery, the Engineers, and in their offshoots, the Special Sound Ranging and Survey Corps, though its recognition by the authorities of Whitehall, has been scanty and grudging. Some of the old-fashioned generals and staff officers could not be got to see the use of men who had not been trained to field exercises by a long course of drill. What is the good of officers, they said, who are not skilled leaders of men? This is the old crude idea again of destroying Germans with rifles, bayonets, and hand grenades. The falsity of these antiquated notions has now, I believe, been amply demonstrated.

The objection to these men, however, lies a good deal deeper. Even those scientifically educated officers who came into the new armies when they were formed, and were trained by the service of years of warfare superadded to the initial course of drill, have been demobilised in a nearly wholesale manner, without the least regard to even very exceptional qualifications. Many of these were, it seems to me, the very men who ought, above all, to have been retained in the service. Now (though, as I write, improved regulations are being

issued) they are to a great extent to be replaced by the Public School *cum* Sandhurst young gentlemen, who, it appears, are the 'pucca' officers *par excellence*.

The old system of the rule of politician chiefs whose only or main function is to sign the edicts of heads of departments seems to have returned in full force, and the coming of the cleansing Hercules that many people desire for the War Office does not seem to be within the bounds of possibility.

The real cause of the prevailing neglect of science, with all its pernicious results, is that almost all our political leaders have received the most favoured and fashionable form of public school education, and are without any scientific education. An education in classics and dialectics, the education of a lawyer, may be a good thing—for lawyers; though even that is doubtful. For the training of men who are to govern a State whose very existence depends on applications of science, and on the proper utilisation of available stores of energy, it is ludicrously unsuitable. We hear of the judicial frame of mind which lawyers bring to the discussion of matters of high policy, but in the majority of scientific cases it is the open mind of crass ignorance. The result is lamentable : I myself heard a very eminent counsel declare in a case of some importance, involving practical applications of science, that one of Newton's laws of motion was that 'friction is the cause of oscillations'! And the helplessness of some eminent counsel and judges in patent cases is a byword.

As things are, eminence in science is no qualification, it would even seem to be a positive disqualification, for any share in the conduct of the affairs of this great industrial country. The scientific sides of public questions are ignored, nay, in many cases our rulers are unconscious of their existence. Recently in a discussion on the Forestry Bill in the House of Lords a member of that illustrious body made the foolish assertion that forestry had nothing to do with science; all that was needed was to dig holes and stick young trees into them. Could fatuity go further? This hereditary legislator who, as things are, has it in his power to manage, or mismanage, the conversion into available energy of the radiation beneficently showered on a certain area (his area) of this country of ours does not seem to be aware that the growing of trees is a highly scientific industry, that there are habits and diseases of trees which have been profoundly studied, that, in short, the whole subject of silviculture bristles with scientific problems, the solutions of which have by patient labour been to a considerable extent obtained.

Take also the case of the Dyes Industries. The publicists and the good business men—the supermen of the present age—who wish to control and foster an industry which owes its very existence to an English chemist, refuse to have on the Committee which is to manage this important affair any man of scientific eminence, and no remonstrance has any effect. These great business men are as a rule not scientific at all. They are all very well for finance, in other respects their businesses are run by their works-managers, and, in general, they are not remarkable for paying handsomely their scientific assistants.

I myself once heard it suggested by an eminent statesman that an electrical efficiency of 98 per cent. might by the progress of electrical science be increased fourfold! This, I am afraid, is more or less typical of the highly educated classical man's appreciation of the law of conservation of energy; and he is, save the mark, to be our minister or proconsul, and the conservator of our national resources. It is not surprising, therefore, that in connection with a subject which for several weeks occupied a great space in the newspapers, and is now agitating a large section of the community, the nationalisation of our coal mines, there was not a single word, except perhaps a casual vague reference in the Report of the Chairman, to the question, which is intimately bound up with any solution of the problem which statesmen may adopt, I mean the question of the economic utilisation, in the interests of the country at large, of this great inheritance which Nature has bestowed upon us. In short, are Tom, Dick, and Harry, if we may so refer to noble and other coalowners, and to our masters the miners, to remain free to waste or to conserve at their own sweet will, or to exploit as they please, this necessity of the country's existence?

The fact is that until scientific education has gone forward far beyond the point it has yet reached, until it has become a living force in the world of politics and statesmanship, we shall hardly escape the ruin of our country,

The business men will not save us; as has been said with much truth, the products of modern business methods are to a great extent slums and millionaires. It lies to a great extent with scientific men themselves to see that reform is forthcoming; and more power to the Guild of Science and to any other agency which can help to bring about this much-needed result.

While scientifically educated men, whether doing special work or acting as officers, have been held of far slighter account in the services than they ought to have been, for physicists as such there has been little or no recognition, except, I believe, when they happened to be ranked as research chemists! How did this happen? Why, the various trades asserted themselves, and the result was a sufficiently long list of 'reserved occupations,' a list remarkable both for its inclusions and for its exclusions. There was, for example, a class of 'opticians,' many of whom have no knowledge of optics worth mentioning. They are merely traders. One of these, for example, the proprietor of a business, made a plaintive appeal to myself as to how he could determine the magnifying powers of certain field-glasses which he wished the Ministry of Munitions to purchase. But for a young scientific man, even if he were an eminent authority on theoretical and practical optics, but who was not in the trade, there was no place.

Research chemists received their recognition in consequence of the existence of the Institute of Chemistry. I am extremely glad to find that something is now being done to found an Institute of Physics. I hope this movement will be successful, and that it will be thoroughly practical and efficient. I hope its President and Council, its Members and its Associates, will be jealous for science, and especially for physics. It ought to be a thoroughly hard-working body, without any frills, destitute of work value. They have an example in the General Medical Council, which has so effectively cared for the interests of the medical profession.

I am glad that something is being done at last for the organisation of scientific research. This movement has started well in several, if not in all, respects, and I wish it all success. There are, however, one or two dangers to be avoided, and I am not sure—I may be much too timid and suspicious—that they are fully recognised, and that the result will not be too much of a bureacracy. Somehow or other I am reminded by the papers I have seen of the remark of a poor man who, asking charity of someone in Glasgow, was referred to the Charity Organisation Society of that city. 'No, thank you,' he said: 'there is a good deal more organisation than charity about that institution.' So I hope that in the movement on foot the organisation will not be more prominent than the science, and the organisers than the scientific workers.

There is to my mind too much centralisation aimed at. Everything is to be done from London: a body sitting there is to decide the subjects of research and to allocate the grants. There may be a good deal to be said for that in the case of funds obtained in London. But apparently already existing local incentives to research work are to be transferred to London. The Carnegie Trust for the Universities of Scotland, soon after its work began, inaugurated a scheme for research work in connection with these Universities. The beneficiaries of the Trust, it is well known, must be students of Scottish nationality. The action of the Trust has been most excellent, and much good work has been done. Now, so far as chemistry and physics are concerned, it has been proposed, if not decided, to hand over to the organisation in London the making of the awards, a process of centralisation that will probably not end with these subjects. I venture to protest against any such proceeding. The more incentives and endowments of research that exist and are administered in the provinces the better. Moreover, this is a benefaction to Scottish students which ought not to be withdrawn and merged in any provision made for the whole country, and administered in London by a bureau which may know little of the Scottish Universities or of Scottish students. The bureau might, with equal justice or injustice, be given command of the special-research scholarships of all the Universities both in England and Scotland, and administer them in the name of the fetish of unification of effort. I do not know, but can imagine, what Oxford and Cambridge and Manchester and Liverpool would say to that. But even Scotland, where of course we know little or nothing about education

of any kind, may also have something to say before this ultra-centralisation becomes an accomplished fact.

There is, it seems to me, another danger to be avoided besides that of undue centralisation in London. In most of the statements I have seen regarding the promotion of research work the emphasis seems to be on industrial research, that is in applied science. This kind of research includes the investigation of physical and chemical products of various kinds which may be used in arts and manufactures, and its deliberate organised promotion ought to be a commercial affair. I observed, by the way, with some amusement, that according to the proposals of one Committee for Applied Science, which is prepared to give grants and premiums for researches and results, the Professor or Head of a Department, from whom will generally come what are most important, the ideas, is to have no payment. He is supposed to be so well paid by the institution he belongs to as to require no remuneration for his supervision of the Committee's researches. And the results are to be the sole property of the Committee!

There is in this delightfully calm proposal at least a suggestion of compulsion and of interference with institutions and their staffs, which ought to be well examined. Also some light is thrown on the ideas of such people as managing directors of limited liability companies, who are members of such a committee, as to what might reasonably be expected of men of high attainments and skill, whose emoluments taken all round are on the whole miserably insufficient.

I think that it is in danger of being forgotten that, after all, pure science is by far the most important thing. Most of the great applications of science have been the products of discoveries which were made without any notion of such an outcome. Witness the tremendous series of results in electricity of which the beginning was Faraday's and Henry's researches on induction of currents, and the conclusion was the work of Hertz on electric waves. From the first came the production and transmission of power by electricity, from the last the world has received the gift of wireless telegraphy. I am not at all sure whether the great men who worked in the sixty or seventy years which I have indicated would have always received grants for proposed researches, which to many of the good business directors and other supermen serving on a great bureau of investigation, had such then existed, would have appeared fantastic and visionary. In research, in pure science at least, control will inevitably defeat itself. The scientific discoverer hardly knows whither he is being led; by a path he knows not he comes to his own. He should be free as the wind. But I must not be misunderstood. Most certainly it is right to encourage research in applied science by all available and legitimate means. But beware of attempting to control or 'capture' the laboratories of pure science in the Universities and Colleges of the country. Let there be also ample provision for the pursuit of science for its own sake; the return will in the future as in the past surpass all expectation.

I had intended to say something about scientific education as exemplified by the teaching of physics. I have left myself little time or space for this. I cannot quite pass the matter over, but I shall compress my remarks. In the first place I regard dynamics, especially rotational dynamics, as the foundation of all physics, and it is axiomatic that the foundation of a great structure should be soundly and solidly laid. The implications of dynamics are at present undergoing a very strict and searching examination, and now we may say that a step in advance has been taken from the Newtonian standpoint, and that a new and important development of dynamics has come into being. I refer of course to the new theories of relativity, which are now attracting so much attention. I hope to learn from the discussions, which we may possibly have, something of the latest ideas on this very fundamental subject of research. It is a matter for congratulation that so many excellent accounts of relativity are now available in English. Some earlier discussions are so very general in their mathematical treatment and notation as to be exceedingly difficult to master completely. I have attacked Minkowski's paper more than once, but have felt repelled, not by the difficulties of his analysis, but by that of marshalling and keeping track of all his results. Einstein's papers I have not yet been able to obtain. Hence it is a source of gratification to have Professor Eddington's interesting Report to the Physical Society and the other excellent treatises which we have in English,

But continual thought and envisaging of the subject is still required to give anything approaching to instinctive appreciation such as we have in ordinary Newtonian dynamics. I venture to say that the subject is pre-eminently one for physicists and physical mathematicians. In some ways the new ideas bring us back to Newton's standpoint as regards so-called absolute rotation, a subject on which I have never thought that discussions of the foundations of dynamics had said absolutely the last word.

The better the student of physics is grounded in the older dynamics, and especially in the dynamics of rotation, the sooner will he be able to place himself at the new point of view, and the sooner will his way of looking at things begin to become instructive.

With regard to the study of physics in our Universities and Colleges, I had written a good deal. I have put that aside for the present, and will content myself with only a few general observations. First, then, it would, I think, be conducive to progress if it were more generally recognised that dynamics is a physical subject, and only secondarily a mathematical one. Its study should be carried on in the departments of physics, not in those of mathematics or in separate departments of applied mathematics. It is, or ought to be, essentially a subject of the physical lecture-room and the physical laboratory. The student should be able to handle rotating bodies, to observe and test the laws of precession and nutation, to work himself, in a word, into an instinctive appreciation of at least the simpler results of rotational theory. He should learn to think in vectors, without necessarily referring either to Hamilton or to Grassmann. Some people appear to censure the use of vector ideas without the introduction at the same time of some form of vector notation. I do not feel drawn to any system of vectors in particular—all have their good points, and in some ways for three dimensional work the quaternion analysis is very attractive—but vector *ideas* are of the very utmost importance.

Hence I deprecate the teaching, however elementary, which as a beginning contents itself with rectilineal motion. The true meaning of rate of change of a directed quantity, even of velocity and acceleration, is missed, and instead of having laid a foundation for further progress the teacher, when he desires to go beyond the mere elements, has practically to relay his foundations, has in fact to extract imperfect ideas from his pupils' minds and substitute new ones, with the result that a great deal of avoidable perplexity and vexation is produced. The consideration of the manner of growth of vectors—the resultant vector or it may be component vectors, according to convenience—is the whole affair. As an illustration of what I mean, take this: A vector quantity has a certain direction, and also a magnitude L. It is turning in a certain plane with angular speed ω. This turning causes a rate of production of the vector quantity about a line in that plane and perpendicular to the former, and towards which the former is turning, of amount $L\omega$. Thus a particle moving in a curve with speed v has momentum mv forwards along the tangent at the position of the particle. The vector is turning towards the principal radius (length R) of curvature at the point at rate v/R. Hence towards the centre of curvature momentum is growing up at time rate mv^2/R.

Dealt with in this way, with angular momentum instead of simple momentum, the motions of the principal axes of a rigid body give the equations of Euler instantly and intuitively, and all the mind-stupefying notions of centrifugal couples, and the like, are swept away.

With regard to mathematics, the more the physicist knows the better, and he should continually add to his store by making each physical subject he takes up a starting-point for further acquisition. Some very philistine notions as to mathematics prevail, and are very mischievous. For example, I once heard an eminent practical engineer declare that all the calculus an engineering student requires could be learned in an hour or two. This is simply not true, nor is it true, as some exponents of ultrasimplicity seem to suggest, that the professional mathematical teacher wilfully makes his subject difficult in order to preserve its esoteric character. Like the engineer or physicist himself, he is not always so simple as he might be; but the plain truth is that no good progressive mathematical study can be carried out without hard and continued application of the mind of the student to the subject. And why should he

plenty of excellent books. If he has a determination to help himself he will, if depend on the mathematical teacher? Let him be his own teacher! There are he makes a practice of reserving difficulties and returning to them, find them vanish from his path.

As I have said, I am specially interested in rotational dynamics. In the course of the war I have been appalled by the want of appreciation of the principles of this subject, which, in spite of considerable acquaintance with the formal theory, seemed to prevail in some quarters. I don't refer to mistakes made by competent people—it is human to err—but to the want of appreciation of the true physical meaning of the results expressed by equations. A gyrostat as ordinarily considered is a closed system, and its dynamical theory is of a certain kind. But do away with the closedness, and the dynamical theory is quite a different affair. Take, as an example, the case of two interlinked systems which are separately unstable. This compound system can be made stable even in the presence of dissipative forces. A certain product of terms must be positive, so that the roots of a certain determinantal equation of the fourth degree may all be positive. The result shows that there must be angular acceleration, not retardation, of the gyrostat frame. This acceleration is a means of supplying energy from without to the system, the energy necessary to preserve in operation the functions of the system.

I have ventured to think this stabilising action by acceleration of the compound motion very important. It is lost sight of by those who consider and criticise gyrostatic appliances from the usual and erroneous point of view. Also I believe that it is by analogy a guide to the explanation of more complicated systems in the presence of energy-dissipating influences, and that the breaking down of stability or *death* of the system is due to the fact that energy can no longer be supplied from without in the manner prescribed for the system by its constitution.

I had just concluded this somewhat fragmentary address when the number of *Nature* for July 24 came to hand, containing a report of Sir Ernest Rutherford's lecture at the Royal Institution on June 6. The general result of Sir Ernest's experiments on the collision of α-particles with atoms of small mass is, it seems to me, a discovery of great importance, whatever may be its final interpretation. The conclusion that 'the long-range atoms arising from the collision of α-particles with nitrogen are not nitrogen atoms, but probably charged atoms of hydrogen or atoms of mass 2,' is of the utmost possible interest. The α-particle (the helium atom, as Rutherford supposes it to be) is extraordinarily stable in its constitution, and probably consists of three helium nuclei each of mass 4, with two attached nuclei of hydrogen, or one attached nucleus of mass 2. The intensely violent convulsion of the nitrogen atom produced by the collision causes the attached nuclei, or nucleus, to part company with the helium nuclei, and the nitrogen is resolved into helium and hydrogen.

It seems that, in order that atoms may be broken down into some primordial constituents, it is only necessary to strike the more complex atom with the proper kind of hammer. Of course, we are already familiar with the fact that radio-active forces produce changes that are never produced by so-called *chemical* action; but we seem now to be beginning to get a clearer notion of the *rationale* of radio-action. It seems to me that it might be interesting to observe whether any, or what kind of, radiation is produced by the great tribulation of the disturbed atoms and continued during its dying away. If there is such radiation, determinations of wave lengths would be of much importance in many respects.

I may perhaps mention here that long ago, when the cause of X-rays was a subject of speculation, and the doctrine that mainly found acceptance was that they were not light waves at all, I suggested to the late Professor Viriamu Jones that radiation of extremely small wave length would be produced if atomic or molecular vibration, as distinguished from what in comparison might be called molar vibration, could be excited. An illustration that suggested itself was this: Take a vibrator composed of a series of small masses with spring connections. If these masses are of atomic or molecular dimensions any ordinary impulse or impact would leave them unaffected, while vibrations of groups of them, depending on the connections, would result. But

the impact on one of the masses of a hammer of sufficiently small dimensions, and mass would give vibrations depending on the structure of the mass struck, and independent of the connections, just as the bars of a xylophone ring, while the suspended series of bars, if it swings at all, does so without emitting any audible sound. This is, I believe, in accordance with the theory now held as to X-rays. We now have some information as to the mode of producing a local excitement so intense as to cause not merely atomic disturbance, but actual disruption of the atomic structure. Further developments of Sir Ernest Rutherford's experiments and of his theory of their explanation will be eagerly awaited.

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ADDRESS

TO THE

CHEMICAL SECTION

BY

PROFESSOR P. PHILLIPS BEDSON, D.Sc.,

PRESIDENT OF THE SECTION.

In again taking up the work of this Section, after an interval of three years, a discontinuity without parallel in the annals of the Association, it is natural that our thoughts should turn to the past, and in so doing we are reminded of the gaps in the ranks of those who were accustomed to contribute to the work of our Section. In 1916 we met under a shadow caused by the death of Sir W. Ramsay, whose genius has added in so many ways to our science. And to-day we have to record the loss of one who in his long life contributed in a variety of ways to the advancement of chemistry, and to whom we owe an addition to the number of elementary substances in the discovery of thallium, one of the early fruits of the use of the spectroscope. The chemistry of the rare earths has been especially illumined by the researches of Sir William Crookes. With physicists we would join in a tribute to the memory of Lord Rayleigh, amongst whose experimental researches is one of special interest to chemists—namely, the revelation of the existence of argon, of which discovery Sir J. J. Thomson has recently written that it was not made 'by a happy accident, or by the application of new and more powerful methods than those at the disposal of his predecessors, but by that of the oldest of chemical methods—the use of the balance.'

In this connection it is but right that, despite the feelings engendered by the war, I should refer to the passing of two great chemists—Baeyer and Fischer. The former died some two years ago, and the latter within the past few months. Each of them has advanced by his experimental researches the progress of organic chemistry, and has brought illumination into many of the obscure departments of this branch of science. The field of investigation latterly cultivated by Fischer has revived an interest in the 'vital' side of organic chemistry as distinguished from the study of the chemistry of the carbon compounds. Moreover, there are many British chemists, amongst them some of the most distinguished, who, as students, received guidance and inspiration from the teaching of Baeyer or of Fischer, and with them we gratefully acknowledge our indebtedness.

Fifty years ago Mendeléeff communicated to the Russian Chemical Society a memoir which has exercised a profound influence on chemical philosophy, and continues to serve as a guide in the interpretation of research and speculations on the nature of the elements. Without entering on the somewhat vexed question as to whom should be assigned the credit of the discovery of the Periodic Law, I trust I shall not be considered unmindful of the claims of Newlands, by adopting the traditional history, and, as is usual, associate this discovery with the name of Mendeléeff, and consequently we may look on this year as the Jubilee of the Periodic Law. Although there is already abundant special literature dealing with this subject, and the periodic system has been assimilated into the teaching of the science and is dealt with in the text-books of chemistry, in some of which it forms the basis of the system employed in the exposition of the

facts and theories of inorganic chemistry, still it appeared to me that I might utilise this as an opportunity of passing in brief review some of the features of the rise and development of the 'Periodic Law.'

The memoir, made known to the non-Russian reader by the abstract in German, shows the principle of periodicity—viz., the recurrence of similar properties at regular intervals with increase in the magnitude of atomic weights, the possibility of utilising the atomic weights as a basis of the classification of the elements, the necessity for the revision of the values thus assigned to the atomic weights of certain elements, and finally that the scheme demanded for its completeness the existence of many new elements.

The later writings of Mendeléeff contain the mode of tabulating the elements in the form usually adopted in chemical text-books, portraying the principle of periodicity and showing the grouping of the elements into natural families. But undoubtedly the clearest demonstration of the association between the atomic weights and the physical properties of the elements is that exhibited by the curve of atomic weights and atomic volumes, which is an outcome of the independent studies of these relationships by Lothar Meyer, and, as is well known, shows the members of the natural families of elements occupying corresponding positions on the curve. This curve, with its undulations, corresponding to the series of the elements, has contributed to impress on the mind of the student the relationship between the properties of the elements and their atomic weights, and may have exercised an influence in drawing attention to these relationships which the attempts of the earlier workers in this field were not successful in doing.

Mendeléeff's Table of the Elements was just beginning to figure in the teaching of chemistry in my undergraduate days, and, together with the speculations underlying it, aroused considerable interest and proved an incentive and inspiration for experimental inquiry. Foremost in this country amongst those who by their writings have contributed to spread a knowledge of Mendeléeff's speculations was my fellow-student, Carnelley. His experimental investigations added materially to our knowledge and definition of the physical properties of elements and compounds, which further emphasised the periodicity in the relation of the atomic weights to the properties of the elements, and have provided data from which curves, resembling in contour the atomic volume curve, have been set up.

A valuable guide in fixing the atomic weights of the elements has been the specific heat which, as the discovery of Dulong and Petit showed a hundred years ago, varies in the case of solid elementary bodies inversely with their atomic weights; or, as is more usually expressed, the solid elements have the same atomic heat. The investigation of the exceptions to this empirical rule brought out the fact that the specific heat is influenced by temperature, and the study of the influence of low temperatures led Sir James Dewar to the discovery that at about 50° Absolute the atomic heats of the elements are a periodic function of the atomic weights. Further, the graphic representation of this relation gives a curve very similar in its course to that of the atomic volume curve. So that the specific heat is another of the physical properties to fit into the periodic scheme.

The necessity for a revision of the atomic weights of certain elements, as pointed out by Mendeléeff, has induced several workers to direct their energies to the solution of the problems indicated, so that in our present-day tables many of the anomalies of position and sequence which existed in the earlier schemes have disappeared. Tellurium has still resisted all attempts to bring it into order, with an atomic weight less than that of iodine, which its association with sulphur and selenium demands. The interesting attempts to decompound tellurium have so far remained unfruitful.

But undoubtedly the most fascinating feature of the periodic system is that 'it allows the discovery of many new elements to be foreseen.' This and the manner in which Mendeléeff, in full conviction of the truth of the 'Periodic Law,' boldly assigned properties to those elements required to fill the blank spaces in the table of the elements, and the verification within twenty years in three instances of these prophetic specifications have contributed to the recognition and firm establishment of the 'Periodic Law' as an article of belief in

chemical philosophy, and to make it the mainspring and inspiration of the greater part of modern inorganic research.

The discovery of argon, the announcement of which formed a notable feature in the proceedings of the Association at the Oxford meeting in 1894, and the recognition in it of an element with an atomic weight of 40, raised doubts in the minds of some as to the validity of the scheme of the elements based upon the Periodic Law. It was indeed a time of testing the faith. The suggestion that argon would prove to be a modified form of nitrogen was brushed aside by the incontrovertible establishment of it as an element, endowed only with specific physical properties and distinguished from all known elements by its lack of any of those activities which characterise the remaining elements. But argon was not destined to enjoy a splendid isolation for long. The researches of Sir W. Ramsay soon brought helium to earth, and he and his colleagues provided a number of companions for argon. So, in a very short period, was recognised the existence of a group of gaseous elements forming a natural family, whose molecules are monatomic, the members of which are distinguishable by their spectra and atomic weights, but are all in agreement in their unreadiness to take part in any chemical change. This inertness or nonvalence provided a simple means of reconciliation with the periodic scheme of the elements, as all that was required was simply to add to the eight groups of the table of elements a zero group containing helium, neon, argon, krypton, and xenon, and with niton, the emanation from radium, as a recent addition. If we are to accept Mendeléeff's suggestion, the zero group should contain a member lighter than hydrogen, in Series I., and in a zero series a still lighter representative of the elements of the zero group, which he has postulated as the 'ether' of the physicist.

Thus the discovery of argon has formed a starting point in the development and a justification of the natural system of the elements, but it still remains, to make the tabulation complete, that provision should be made for the accommodation of the rare earths. The paper published by Werner in 1905, under the title 'A Contribution to the Development of the Periodic System,' shows how this can be satisfactorily accomplished.

The elements of the argon group form a valuable extension to the periodic system, and the knowledge acquired in the investigation of these substances has proved serviceable in the solution of problems in the realms of science and of industry. The knowledge of the properties and behaviour of helium was destined soon to play a part in the solution of the riddle of the radio-active elements, whilst it is specially noteworthy that argon, the 'idle one,' should have been pressed into industrial service.

This fact suggests the thought that idleness has its uses, and at the present time how satisfactory would it be were we able to find useful application for a quality which appears to be plentifully and widely distributed in this country.

The history of helium is still more astonishing, for not until thirty years after its existence had been surmised from spectroscopic observations of the sun was this element found to have a terrestrial existence, and now, as one of the achievements of science during the war, we may look on its production in bulk as a commercial proposition. Moreover, we are told 'that the advances made in the production of helium warrant the opinion that, had the war continued after November 11, 1918, supplies of helium at the rate of 2,000,000 cubic feet per month would have been produced within the Empire and the United States, and helium-filled aircraft would have been in service.' [1]

Some of the speculations that the periodic system of the elements has given rise to have been the subjects of communications to this Section.

At the Aberdeen meeting Carnelley, whom I have already mentioned as an ardent worker in this field, gave an account of a scheme based on the conception that the elements are composite, having relations similar to those exhibited by the paraffin hydrocarbons and the isologous series of radicals derived from them. He regarded the elements, other than hydrogen, as made up of two simple elements, A and B. A he identified with carbon, with the atomic weight of 12, and B was assumed to have a negative atomic weight of 2.

[1] *Nature*, July 17, 1919.

In the following year, at Birmingham, Sir W. Crookes devoted his address to this Section to an exposition of his ideas of the 'Genesis of the Elements,' a subject to which he on many subsequent occasions returned, and amplified in the light of recent discovery. The process of evolution of the elements from a primal 'protyle' is depicted as taking place in cycle after cycle, in each cycle the 'unknown formative cause' scattering along its journey clusters of particles corresponding to the atoms of the 'elements,' forming in this way a series such as that beginning with hydrogen and ending with chlorine; a repetition of the movement under somewhat altered conditions giving rise to a series of similarly related elements, and thus homology, which is shown by the members of the natural families, is provided for.

The investigations of Sir J. J. Thomson on the discharge of electricity through gases have established the divisibility of the atoms, and in his 'Corpuscular Theory of Matter' he has given us conceptions of how atoms may be constituted to provide a series so related that they reflect, if not reproduce, many of the chemical characters of the elements and their periodic relation to atomic weights.

With the discovery of radium and its remarkable properties we have been brought in contact with an element undreamt of in our philosophy. The interpretation of the results of the investigation of this element has called for drastic changes in our conception of an element. The pursuit of the researches of the radio-active elements, guided by the theory of the spontaneously disintegrating atom propounded by Rutherford and Soddy, has served to reveal facts which lend a special emphasis to many passages in the address of Sir W. Crookes to which I have already referred.

For instance, the passage in which he said: 'Should it not sometimes strike us, chemists of the present day, that after all we are in a position unpleasantly akin to that of our forerunners, the alchemists of the Middle Ages? The necromancers of a time long past did not, indeed, draw so sharp a line as do we between bodies simple and compound; yet their life-task was devoted to the formation of new combinations, and to the attempt to transmute bodies which we commonly consider as simple and ultimate—that is, the metals. In the department of synthesis they achieved very considerable successes; in the transmutation of metals their failure is a matter of history.'

Or again, when he propounded the question, 'Is there, then, in the first place, any direct evidence of the transmutation of any supposed "element" of our existing list into another, or of its resolution into anything simpler?'—a question to which he, Sir William Crookes, was at that time forced to reply in the negative, whereas to-day many instances might be cited in support of an affirmative answer to this question. Radio-activity has supplied a method of analysis—radio-active analysis—surpassing in delicacy any of the previously known methods for the examination of material substance; the application of these methods has not only added to the list of elements but also new classes of elements. First, elements indistinguishable and inseparable by chemical means, yet differing slightly but definitely in their atomic weights. The existence of these 'isotopes,' as Soddy styles them (a name giving prominence to the fact that such elements occupy the same place in the table of the elements), demonstrates that absolute uniformity in the mass of every ultimate atom of the same chemical element is not an essential, but that 'our atomic weights merely represent a mean value around which the actual atomic weights of the atoms vary within certain narrow limits.'[2]

Whether the possibility of separating isotopes, recently suggested by Dr. Lindemann and Dr. Chapman, will be found capable of experimental realisation, must be left to the future to decide; in fact, in this matter we must adopt the attitude, prevalent in other than scientific circles, of 'wait and see.'

The investigations in the field of radio-activity have further brought to light that identity in atomic weight may be associated with difference in chemical properties, revealing the existence of a further class of elements for which Dr. Stewart suggests the name 'isobares.' Further, Dr. Stewart considers that

[2] Crookes. Address to Section B. 1886.

isobaric elements are to be found not alone amongst the radio-active, but some of the normal elements exhibit properties which may be explained on the assumption that they are isobarics. Thus the compounds formed from iron are regarded as indicating the existence of three irons, all having the same atomic weight. One of these, termed ferricum, is tervalent; one, ferrosum, is divalent; whilst the third, ferron, is inert and takes no part in chemical changes. The three are under certain conditions mutually interconvertible. This last condition does not apply in the case of the radio-active isobares.

The elements are to be regarded as divisible into three classes: (1) Isotopic elements, each set of which have different atomic weights but identical chemical properties; (2) Isobaric elements which have identical atomic weights but different chemical properties; (3) Normal elements which differ from each other both in atomic weights and chemical properties.

The discovery of X-rays may be acclaimed as having added a new sense to aid us in our investigation of material objects, and to their innumerable services may be reckoned the results which have followed from the investigations of the X-ray spectra of the elements by the late Lieut. Moseley, whose death in Gallipoli in 1915 is one of the many tragedies of the war specially deplored in the scientific world. From the analysis of the X-ray spectra, Moseley has shown that for each element a value can be deduced, which is styled the atomic number and which represents the space in the atomic table the element should occupy. The researches of Rutherford and Andrade on Lead and Radium B have proved that 'isotopes' have the same atomic number. Whatever may be the ultimate explanation of the meaning of the atomic numbers, their experimental determination has already proved valuable in the solution of some of the anomalies of the Periodic Table. In addition to the case of isotopes, just referred to, the number of elements between hydrogen and uranium is fixed by finding 92 as the atomic number for uranium, and further, Moseley's work has revealed that the atomic numbers are in agreement with the order of the chemical sequence, rather than the order of the atomic weights, which is of special interest and value in the cases of tellurium and iodine, and of potassium and argon, the decision in each case proving a welcome support to the position in the table assigned to these elements on chemical considerations.

Again, Moseley's atomic numbers remind us of the arrangement of the elements adopted by Newlands in his communication to the Chemical Society of 1866, in which he set forth the 'Law of Octaves,' the precursor of the Periodic Law.

In concluding this brief sketch, cognisance should be taken of the speculations of physicists as to the structure of the atom. Already several models of the atom are in the field which leave the uncuttable Daltonian atom far out of view, still in a measure they help to an understanding of some of those regularities exhibited by the elements, and set forth in the natural system. Valency and its vagaries, which we are accustomed to describe by phrases, such as 'variable valency,' 'selective valency,' and the like, still call for a full explanation.

I purpose now to direct attention to matters of another nature, which appear to me of interest to chemists, and to that extent have a bearing on the welfare of chemistry in this country.

Among the numerous revelations and surprises of the past five years has been the realisation on the part of the public and the Government of the importance of the chemical industries to the national well-being. The apathy and indifference of pre-war times were replaced by an apparently lively interest in things chemical, and there was what in the religious world would be styled a revival.

Politicians, the Press in all its varied forms, daily, weekly, monthly, and quarterly, took up the subject of our industrial insufficiencies and emphasised in various ways the importance of research in connection with our industries. Again, the coal-tar colour industry furnished, as it had done again and again, some thirty to forty years ago, the text from which research and its importance was preached. This time the reiteration had the effect that the 'aniline phantasm,' as I have seen it described, was recognised as a 'key industry,' important to the vitality of the manufacture of textiles; with the result that the Government, discarding its fiscal policy, was induced to subsidise the

enterprise for the manufacture of dyes and other coal-tar products. The negotiations preceding the formation of the 'British Dyes Co., Ltd.,' have been remarkable as revealing that in the eyes of some, at any rate, special knowledge is a 'dangerous thing,' and, in fact, was deemed sufficient to exclude its possessors from a seat on the directorate. This is all the more remarkable as the history of similar enterprises in Germany shows the *personnel* of the directorates to be made up of university-trained men and, in not a few instances, of professors. So that in Germany academic distinction and theoretic learning are not considered as excluding the possession of commercial acumen and those other qualities needed in a successful man of business.

In the early stages of the war the demand for explosives was met by the expansion of already existing factories, the increase in staff of which called for many additional men with chemical training, a call which became unprecedented and insistent when the national factories were founded, so that men and women with a chemical training found an opportunity of putting their knowledge at the service of their country. And in not a few instances those who, for financial reasons, had at the close of their college career taken up a less congenial employment were able to return to the practice of chemistry, for which in their student days they had specially fitted themselves.

In the foreword of the publication 'Reports on Costs and Efficiencies for H.M. Factories,' issued by the Ministry of Munitions, we are told 'when it was decided to commence the erection of new and national factories, and an attempt was made to collect from existing factories the necessary technical data and assistance, did it become evident that, due to the extraordinary demands of the war, there was—practically throughout the entire country—a regrettable lack of available accurate technical data, and an even greater lack of trained technical men—more particularly chemical engineers.'

To anyone acquainted with the conditions existing in this country in pre-war days, the lack of 'trained technical men' is no matter of surprise. In fact, one cannot fail to be astonished at the phenomenal development of chemical manufacture which has taken place under the directing influence of Lord Moulton, in response to the call from Army to Navy. That men were found capable of taking a part in these varied undertakings, cannot, at any rate, be credited to the encouragement which the teaching of chemistry or the students of the science had received from those directing industries, which employ or should employ the services of chemists. It is no uncommon experience to find the chemist employed simply in the analytical testing of raw materials and manufactured products, and even in the working of processes under their control the potentiality of the chemist is not utilised to the full, as is evident from the following, which is a quotation from the Preface to the brochure, issued by the Ministry of Munitions, to which I have already referred: 'Since the beginning the policy of the Department with regard to our national factories has been to aim at maximum efficiency in respect of cost and usage of materials.

'For this purpose the greatest efforts have been made to place before all those who are in any way responsible for control full details concerning the working and costs of the factories. This was rather an innovation in the field of chemical manufacture, as until comparatively recently, either intentionally or through negligence, it was customary at many chemical plants to keep the chemists in complete ignorance not only of the cost at their plants but also even of the efficiencies.

'It is amazing that manufacturers can expect improvements in chemical processes when their chemists are kept in ignorance of such vital facts.

'It has happened very often that as soon as detailed figures were seen by chemists at a plant, important alterations and improvements have at once been suggested, the need for which would otherwise never have been noticed.'

The condition of service indicated in the passage quoted, together with the low scale of remuneration which obtained hitherto in chemical industries, help to explain the scarcity of the kind of scientific labour referred to in the quotation I have made from the 'Foreword.'

But are we not told and invited to believe that all this is changed, that the records of the magnificent achievements of British chemists in the war have so

educated the people and, may we say, the Government also, that the practitioners in chemistry will no longer find it essential that in describing their vocation they should be required to add, unless for special reasons, such prefixes as 'analytical,' 'research,' 'scientific,' or 'engineering' to the word chemist, secure in the feeling that by describing themselves as 'chemists' their standing, training, and profession will be correctly understood.

Still a feeling akin to despondency, if nothing worse, is pardonable, when realising the fundamental importance of chemistry to our industries, and the thousand and one ways chemical research has ministered to the amenities of our every-day life, there should exist not alone in the mind of the general public, but of the educated also, such a lack of information as has been revealed during the past few years. To wit, the myth woven into the history of the production of glycerine, the confusion in the minds of legislators between phosphates and phosgene. More serious, however, is the fact that the method of investigation employed by the chemist is so little appreciated or understood as to lead one to imagine that the discoveries and achievements are the results of a species of legerdemain. The production of new colours, a succession of happy thoughts, and that 'by an accident the secret of synthetic indigo was unlocked.' This last is a quotation from a review entitled 'The Value of Scientific Research,' published some three years ago, and is typical of much that passes muster in appraising the value of chemical research. That the unravelling of the constitution of indigo which occupied Baeyer and his pupils some thirteen years, the account of these investigations covers some 180 pages of Baeyer's collected works, should be summarised in this way appeared to me to call for a protest. My protest was made and I attempted to put the matter in the correct light, showing the synthesis of indigo to be, indeed, a brilliant example of the value of theory and of a practical illustration of the importance of the chemist's conception of the Architecture of Molecules, as exemplified by Kekulé's theory of the constitution of benzene. The protestation evoked a reply from a correspondent, signing himself D.Sc., Ph.D., who sought to justify the description of the revelation of the secret of synthetic indigo by reference to an accident which occurred in the investigation of the processes for the manufacture of phthalic acid and which certainly greatly facilitated the production of this substance, an intermediate in the manufacture of artificial indigo. So, if the initiated emphasise the unessential, why should we blame the layman and be surprised that well-ordered and planned design should appear to be but the workings of chance, for every such achievement is a witness to the conquest of well-founded theoretical speculation.

But I do not wish to conclude on a despondent note, nor is it right that I should do so, in view of the many activities operating for the promotion of scientific research, and of such evidence as that supplied by the magnificent endowment of the Chemical Department of the University of Cambridge, all of which are evidences of what we may reasonably hope to be a happy augury for the future of chemistry and chemists in this country.

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ADDRESS

TO THE

GEOLOGICAL SECTION

BY

J. W. EVANS, D.Sc., LL.B., F.R.S.,

PRESIDENT OF THE SECTION.

I propose in my address to consider the methods by which the progress of geological research may be most effectively promoted, and to point out some directions in which I think it possible important advances may be made in the early future.

One of the most striking features of our science is the need in which it stands of a large and widely distributed body of workers, and the opportunities it affords to every one of them of making important contributions to scientific knowledge.

Every locality has its geological history stretching away into the 'dark backward and abysm of time,' and this history has left its records in the rocks of the earth's crust: an imperfect record, it is true, for much of it has long since been destroyed, but enough remains to reward long years of patient labour in deciphering it.

Everywhere some one is needed who will devote his spare time to the examination of the quarries and cliffs, where the materials that build up the solid earth are exposed to view, and who will record the changes that occur in them from time to time; for a quarry that is in work, or a cliff that is being undermined by the sea, constantly presents new faces, affording new information, which must be recorded if important links in the chain of evidence are not to be lost. It is equally important that some one should always be on the look-out for new exposures, road or railway cuttings, for instance, or excavations for culverts or foundations, which in too many instances are overgrown or covered up without receiving adequate attention. It is, again, only the man on the spot who can obtain even an approximately complete collection of the fossils of each stratum and thus enable us to obtain as full a knowledge as is possible of the life that existed in the far-off days in which it was laid down. In his absence, many of the rarer forms which are of unique importance in tracing out the long story of the development of plants and animals, and even man himself, never reach the hands of the specialist who is capable of interpreting them. It was an amateur geologist, a country solicitor, who saved from the roadmender's hammer the Piltdown skull, that in its main features appears to represent an early human type, from which the present races of man are in all probability descended. Another amateur, who was engaged in the brick-making industry near Peterborough, has provided our museums with their finest collections of Jurassic reptiles. A third, a hard-worked medical man, was the first to reveal the oldest relics of life

that had at that time been recognised in the British Isles; and many more examples could be instanced of the services to geological science by those whose principal life-task lay in other directions.

Such workers are unfortunately all too few—fewer, I fancy, now than they were before the pursuit of sport, and especially of golf, had taken such a hold upon the middle classes and occupied so considerable a portion of their leisure hours and thoughts. One might hope that the extended hours now assured to the working classes for recreation would lead to a general increase of interest in science among them, if it were not that the students of that admirable organisation, the Workers' Educational Association, seem almost invariably to prefer economic or political subjects to the study of nature, a choice in defence of which they could no doubt advance most cogent arguments. In a large county in which I am interested the number of those in every condition of life who are able and willing to take part in geological research might be told almost on the fingers of one hand, and so far as I am aware there has not been a single recruit in recent years from the ranks of the younger men or women.

It seems strange that there are so few of our fellow-countrymen or country-women who feel a call to scientific research, especially in a subject which, like geology, makes a strong appeal to the imagination, telling us of the strange vicissitudes through which our world and its inhabitants passed before they assumed the guise and characters with which we are familiar. How few are there who realise that the prolific vegetation to which we owe our wealth of coal was succeeded after the lapse of incalculable years by far-stretching deserts, and these, after continuing for a period still longer in duration, were submerged beneath wide inland semi-tropical seas, under whose waters were accumulated the sediments of sand and mud and calcareous *débris* out of which the fertile valleys of Central England have been carved; or that the conditions under which we now live were only reached through the portals of bleak, desolate ages of excessive cold, the reasons for which we are still at a loss to understand.

Even if the appeal to the imagination were not a sufficient incentive to the cultivation of geology, one would have thought its economic importance would have been effective. Its intimate bearing on the problems of agriculture, engineering, water-supply, and hygiene is too obvious to need emphasis here, and it is scarcely more necessary to point out that all our fundamental manufacturing activities, without exception, are dependent on adequate supplies of materials of mineral origin, so that we need not be surprised that one of the earliest administrative acts of the Imperial Conference was the constitution of an Imperial Mineral Resources Bureau to secure that the whole mineral resources of the Empire should be made available for the successful development of its industries.

It might be suggested that the prevailing indifference to the attraction of geological research was due to a conviction that after eighty years of work by the Geological Survey, as well as by University teachers and amateurs, there was little left to be done, and that all the information that could be desired was to be found in the Survey publications. Such a belief can hardly be very widespread, for, as a matter of fact, comparatively few of the general public realise the value of the work of the Geological Survey, and still fewer make use of its publications. Municipal libraries, other than those of our largest provincial centres, are rarely provided with the official maps and memoirs relating to the surrounding areas, and in the absence of any demand the local booksellers do not stock them. This cannot be attributed to the cost, for, though most of the older maps are hand-coloured and therefore expensive, the later maps—at least those on the smaller scales*—are remarkably cheap, and the memoirs are also issued at low prices.

The true explanation appears to be that a geological map conveys very little information to the average man of fair education who has received no geological instruction. This is certainly not the fault of the Survey maps,

* 1 inch to the mile, 1 : 63,360; ¼ inch to the mile, 1 : 253,440, and 1 inch to 25 miles, 1 : 1,584,000.

which compare very favourably with those of other countries, and have been greatly improved in recent years. In particular, the introduction of a longitudinal section on each map and the substitution of the vertical section drawn to scale for the old colour index must greatly assist those into whose hands it comes in obtaining a correct view of the succession of the strata and the structure of the country. Some of the maps are, it is true, so crowded with information—topographical and geological—that it is frequently difficult, even for the trained geologist, to read them without a lens. This is largely due to the fact that they are printed over the ordinary topographical maps in which there is a great amount of detail that is not required in geological maps. In India the Trigonometrical Survey are always ready to supply, as a basis for special maps, copies of their own maps printed off plates from which a portion of the topographical features have been erased.

The best remedy, however, would be to extend the publication of the maps on a scale of 6 inches to a mile (1 : 10,560). For many years all geological survey work has been, in the first place, carried out on maps of this scale, but they have not been published except in coal-mining areas. There the geological boundaries are printed, but the colouring is added by hand, which makes the maps comparatively expensive. In other localities manuscript copies of the geological lines and colouring on the Ordnance Survey maps can be obtained at the cost of production, which is necessarily considerable.

There is, I believe, a wide sphere of usefulness for cheap colour-printed 6-inch geological maps, especially in the case of agricultural and building land, for which the 6-inch Ordnance maps are already in demand. They afford ample room for geological information, and, accompanied by longitudinal sections on the same scale without vertical exaggeration, their significance would be more readily apprehended than that of maps on a smaller scale. It may be noted that this is the favourite scale employed by those engaged in independent geological research for their field work, and, when the area is not too great, for the publication of their results.

It would be of great advantage if there were a uniform usage by which the position in the stratigraphical series of rock outcrops were indicated by colour and their lithological character by stippling (in black or white or colour) following the ordinarily accepted conventions. This course has been pursued by Professor Watts in the geological map prepared by him to illustrate his 'Geography of Shropshire.' This increases the practical value of the map for many purposes, but is only possible when it is not overburdened with topographical detail.

Some explanation, apart from the maps themselves, is however needed if they are to be rendered, as they should be, intelligible to the general public. The official memoirs which deal with the same areas as the maps do not afford a solution of the difficulty. Excellent as they are from the technical standpoint and full of valuable information, they convey little to the man who has not already a considerable acquaintance with the subject. What is needed is a short explanatory pamphlet for each map, presuming no previous geological knowledge, describing briefly and in simple popular language the meaning of the boundary lines and symbols employed, and the nature and composition of the different sedimentary or igneous rocks disclosed at the surface or known to exist below it in the area comprised in the map. A brief account of the fossils and minerals visible without the aid of a microscope should also be included. The probable mode of formation of the rocks and their relation to one another and the subsequent changes they have undergone should be discussed, and at the same time their influence on the agriculture value of the land and its suitability for building sites, as well as on the distribution and level of underground water, should be pointed out. Some account too should be given of the economic mineral products and their applications.

These pamphlets should be illustrated by simple geographical sections, views of local quarries and cliffs showing the relative positions of the different rocks, figures of the commoner fossils at each horizon, and, where they would be useful, drawings of the forms assumed by the minerals. Each pamphlet would be complete in itself. This would involve a considerable amount of repetition, but it must be remembered that different pamphlets would have as a rule

different readers. An alternative plan would be to follow the example of the United States Geological Survey and reprint the same brief résumé of geological principles in every case with such additions as are required to explain the meaning of individual maps. There can, however, I think, be no doubt that an explanation written expressly for each map can be made at once more easy to understand and more interesting to those without special geological knowledge.

That something further is required to render the information contained in the Geological Survey Maps generally available to the public is illustrated by a correspondence that took place some years ago in one of our leading provincial papers with reference to the achievement of a manipulator of the hazel twig in discovering water in the Triassic rocks of the south-west of Derbyshire. No one seemed to realise that with the help of the Geological Survey Map published forty years before and the contoured Ordnance Survey Map more recently issued, it was possible for anyone who possessed a little geological knowledge and common intelligence to predict within narrow limits the depths at which it would be possible to find water at any point within the area under consideration.

When measures such as I have suggested have been adopted for rendering the publications of the Geological Survey easily comprehensible to the general public, it should be the policy of the Government to obtain for them the widest circulation, so that the information they contain should be generally known, a consummation not only desirable for its own sake as tending to increase the general interest in geology, but because it would be an important factor in developing the industries of the country.

During the war publications containing desirable information were circulated widely and gratuitously by the authorities to all public bodies concerned, and there seems no reason why the information laboriously gathered by the Geological Survey in the national interests and paid for out of the public funds should not now receive the same treatment. All Municipalities, District Councils, public libraries, colleges and schools, both secondary and elementary, should receive free copies of the Geological Survey publications dealing with the area where they are situated or with those immediately adjoining it.

When a new publication is issued the same measures should be taken to make it known locally as a private firm would employ; copies should be sent to the local press, which should be assisted to give an interesting and intelligible account of its contents, with a selection from the illustrations. There should also be a standing notice in the 'Publishers' Circular' of the Survey publications, so that local booksellers may know where to apply for them. I am told that at the present they are sometimes completely ignorant on the subject.

Every facility should, of course, be afforded to the public to make use of the Survey publications. They should not only be on sale at the post offices in the areas to which they relate, but it should also be possible to borrow folding mounted copies of the maps as well as bound copies of the explanations and memoirs, on making a deposit equal to their value. When they were no longer required, the amount of the deposit, less a small charge for use, would be repaid on their return to the same or any other post office and the production of the receipt for cancellation. It would thus be possible, when traversing any part of the country, to consult in succession all the Geological Survey publications of the districts passed through. This system would also enable the permanent residents to refer to the more expensive hand-coloured maps, including the 6-inch manuscript maps, at a comparatively small cost.

The preparation and printing of the explanations of the Survey Maps, and the increase in the numbers printed of other publications, would obviously involve additional expenditure. This would be to some extent set off by increased sales; but even if there were a net loss on the balance, it would be worth while if it enabled the fullest advantage to be taken of the expenditure incurred in any event by the Survey in investigating the mineral resources of the country.

The Survey publications should be illustrated in every museum and school in the districts with which they deal by small collections showing the characters of the local rocks, and of the minerals and fossils that occur in them, and care

should be taken to see that these collections are maintained in good order and properly labelled.

It would be a good plan for the Survey to appoint a local geologist, an amateur or member of the staff of a university or college, in every area of twenty or thirty square miles [1] to act as their representative and as a centre of local geological interest. He would be expected to give his assistance to other local workers who stood in need of it. He would receive little official remuneration, but inquirers in the neighbourhood would be referred to him, and where commercial interests were involved he would, subject to the sanction of the Central Office, be entitled to charge substantial fees for his advice. He would report to the Survey any event of geological importance in the area of which he was in charge—whether it was the discovery of a new fossiliferous locality, the opening of a new quarry,[2] the sinking of a well, or the commencement of boring operations. Many of these matters would be adequately dealt with by local workers, but in other cases it might be desirable for the Survey to send down one of their officers to make a detailed investigation.

One of the most important duties of the Survey, or its local representative, would be to see that the records of well-sinkings and borings are properly kept, and that where cores are obtained the depth from which each was raised is accurately recorded. At the present time the officers of the Survey make every effort to see that this is done, but they have no legal power to compel those engaged in such operations to give the particulars required. Equally important is a faithful record of the geological information obtained in prospecting or mining operations. This is especially necessary where a mine is abandoned.[3] If care is not then taken to see that all the information available is accurately recorded, it may never be possible later to remedy the failure to do so.

Probably these objects would be much facilitated if engineers in charge of boring or mining operations had sufficient knowledge of geology and interest in its advancement to make them anxious to see that no opportunity was lost of observing and recording geological data. This would be in most cases ensured if every mining student were required to carry out geological research as part of his professional training. It is now recognised that no education in science can be considered to be up to University standard if it is limited to a passive reception of facts and theories without any attempt to extend, in however humble a way, the boundaries of knowledge. In the case of geology such research will naturally in most cases take the form of observations in the field. The important point is that the work must be original, on new lines, or in greater detail than before, and not a mere confirmation of published results. It is only by the consciousness that he is accomplishing something which has not been done before that the student can experience the keen pleasure of the conquest of the unknown and acquire the love of research for its own sake.

At present it is disheartening to realise how few of those who have received scientific instruction understood the obligations under which they lie of themselves contributing to the growth of knowledge. If they have once had the privilege of achieving individual creative work they will henceforward desire to take advantage of every opportunity of continuing it.

There is one respect in which geological workers suffer a heavy pecuniary handicap—the cost of railway fares. This affects both the staff and students of colleges, as well as local workers who are extending their radius of work—an

[1] I am afraid that in many parts of the country there are so few amateur geologists that this area would have to be increased, at any rate at first.

[2] It is very desirable that arrangements should be made for the co-operation of the Geological Survey or their local representatives with the Inspectors of Quarries appointed by the Home Office, and that the annual official list of quarries should describe the rocks which are worked, not only by their ordinary economic designations, but also by their recognised geological descriptions.

[3] Those engaged in mining are already required to furnish mining plans to the Mining Record Office, but there is no obligation to give any geological information that may have been obtained. This office was formerly attached to the Geological Survey, but was transferred some years ago to the Home Office.

inevitable necessity in the investigation of many problems. It also seriously interferes with the activity of local Natural History Societies and Field Clubs, the Geological Societies and Associations of the great provincial towns, and, above all, that focus of amateur geological activity—the Geologists' Association of London. It is difficult to exaggerate the importance of these agencies in the promotion of geological education. Both professional and amateur geologists are deeply indebted to the excursions which are in most cases directed by specially qualified workers, with whom it is a labour of love. At the same time one of their most valuable results is the creation of interest in scientific work in the localities that are visited. Now that the railways are, if report speaks truly, to be nationalised, or at any rate controlled by the State, the claims of scientific work carried out without reward in the national interest to special consideration will surely not be ignored. All questions as to the persons to whom such travelling facilities should be extended and the conditions that should be imposed may safely be left to the decision of the Geological Survey, which has always had the most friendly and sympathetic relations with private workers and afforded them every facility and assistance, which their comparatively limited staff and heavy duties permitted.

It is impossible to speak in too generous terms of the Geological Survey[4] and its succession of distinguished chiefs (the last of whom, I am glad to say, is with us to-day), or of the work it has accomplished, in spite of somewhat inadequate financial support from the powers that be, who have taken every precaution that the Honours graduates who join its ranks should do so for the pure love of science and not for the sake of worldly advantage. With increased staff and less straitened finances the Survey would be in a position, not only to discharge the additional duties my suggestions would impose on them, but to extend still further the sphere of their usefulness. There is, for instance, at the present time a very urgent need for the provision of further facilities for the analysis of rocks and minerals to assist and complete the researches both of the official surveyors and of private persons engaged in research. The work is of a very special character, and the number of those who have given sufficient attention to it and understand its difficulties and pitfalls is very limited. The chemical staff at our Universities are chiefly concerned with organic chemistry, and private analysts devote themselves mainly to the examination of economic products. The effect of a hasty excursion of workers of either of these categories into the analysis of such complex silicates as augite or biotite or any of our ordinary igneous rocks is apt to be disastrous, only exceeded in this respect by the results obtained when, as not infrequently happens, a student is given a similar task by way of practice. A certain amount of good work is undoubtedly done in College laboratories, but it is very little in comparison with what is needed.[5]

At present the analytical work of the Survey is organised on a very modest scale in comparison with the *personnel* and equipment of the laboratory of the United States Geological Survey, though the quality of the work has been as a rule in recent years quite as high. There are two analytical chemists attached to the Geological Survey, and some of the other members of the staff are capable of doing good analytical work. The demand, however, for analyses for economic purposes is so great that it is impossible to carry out all the analyses that would be desirable in connection with the purely scientific work of the Survey itself. There is consequently no possibility of their being able to assist private investigators.

Strictly speaking, the individual minerals of a rock should be separately analysed and their relative amounts determined, but this is at present a counsel of perfection that we cannot hope to attain; and when the difficulty of obtaining pure material, especially in the case of fine-grained rocks, and the zoned character

[4] Since 1905 the Irish Survey, a small but enthusiastic band led by one of the most broad-minded of modern geologists, has been separated from that of the remainder of the country.

[5] I should like to refer in this connection to the excellent analytical work of Dr. H. F. Harwood, of the Chemical Department of the Imperial College of Science and Technology.

of practically all complex rock-forming minerals are considered, it is seen that intrinsically it is not quite so important as it would seem to be at first sight. The bulk analysis, intelligently interpreted in connection with the actual mineral composition of the rock as revealed by the microscope, is, in fact, at present the most practical method of determining the composition of the minerals. I need scarcely say that volatile constituents still retained by the rock should be separately determined, and the amount reported as water should not include any other substance given off at the same time.

In the absence of facilities for obtaining rock analyses, petrological work in this country is at present seriously handicapped. A striking illustration of the inadequate provision for analyses is revealed in the fact that for the whole of the early Permian granitic intrusions in the south-west of England, covering nearly 2,000 square miles, and including numerous different types and varieties, there are only four analyses in existence, and of these two are out of date and imperfect. This is all the more remarkable in view of the fact that these rocks are closely connected with the pneumatolytic action that has given us almost all the economic minerals of the south-west of England, comprising ores of tin, tungsten, copper, lead, and uranium, as well as kaolin. If the Survey, by increasing its staff of analysts, were in a position, not merely to multiply the number of analyses illustrating its own work, but to help others engaged in research, they would only be proceeding on lines which have long since been followed in some of our Dominions.

Another direction in which the work of the Survey could with advantage be extended is in the execution of deep borings [6] on carefully-thought-out schemes by which a maximum of information could be obtained. Both in Holland and Germany borings have been carried out to discover the nature of the older rocks beneath the Secondary and Tertiary strata, and Prof. Watts, in his Presidential Address to the Geological Society in 1912 (Proc. Geol. Soc. pp. lxxx.-xc.), has dwelt on the importance of exploring systematically the region beneath the wide spread of the younger rocks that covers such a great extent of the east and south of England. Prof. Boulton, my predecessor in this Chair, has endorsed this appeal, but nothing has been done or is apparently likely to be done in this direction. It seems extraordinary that no co-ordinated effort should have been made to ascertain the character and potentiality of this almost unknown land that lies close beneath our feet and is the continuation of the older rocks of the west and north to which we owe so much of our mineral wealth. It is true that borings have been put down by private enterprise, but, being directed only by the hope of private gain and by rival interests, they have been carried out on no settled plan, and the results and sometimes the very existence of the borings have been kept secret. The natural consequences of this procedure have been the maximum of expense and the minimum of useful information.

Unfortunately in recent years percussion or rope boring, which breaks up the rock into fine powder, has more and more, on account of its cheapness, replaced the use of a circular rotating drill which yields a substantial cylindrical core that affords far more information as to the nature of the rocks and the geological structure of the district. If private boring is still to be carried on, the adoption of the latter procedure should be insisted on, even if the difference of cost has to be defrayed by the Government. It is quite true that a considerable amount of useful information can be collected by means of a careful microscopic examination of the minute fragments which alone are available for study, so that the nature of the rocks traversed can be recognised; but the texture of the rock is destroyed, as well as any evidence which might have been available of its larger structures and stratigraphical relations and almost all traces of fossils. It is, too, impossible to tell with certainty the exact depth at which any par-

[6] I have not space to deal here with the shallow borings in soft strata which have been so successfully conducted on the Flanders front during the war by Captain W. B. R. King, of the Geological Survey. Similar borings have been already carried out by the Survey on a limited scale, but in the light of the experience that has now been gained we may look for a widely extended use of the method both by private workers and by the Survey officers.

ticular material was originally located, for fragments broken off from the sides of the bore may easily find their way to the bottom.

A good illustration, and one of many that might be cited, of the misdirected energy that is sometimes expended in prospecting operations, was afforded a few years ago by a company that put down a boring for oil through more than a thousand feet of granite without being aware of the nature of the rock that was being traversed. In this case a percussion drill was employed, but a few minutes' examination of the material should have enabled the engineer in charge, supposing he had even an elementary knowledge of geology, to save hundreds of pounds of needless expenditure. The sum total of the funds which have been uselessly expended in this country alone in hopeless explorations for minerals, in complete disregard of the most obvious geological evidence, would have been sufficient to defray many times over the cost of a complete scientific underground survey.

If research is to be carried out economically and effectively, it must be organised systematically and directed primarily with the aim of advancing knowledge. If this aim be well and faithfully kept in view, material benefits will accrue which would never have been thought to be sufficiently probable to warrant the expenditure of money on prospecting.

It is, however, not only in the areas occupied by Secondary or Tertiary rocks that systematic boring is urgently needed. There are many other localities where important information as to the structure of the rocks could probably be obtained in this manner. Opinion is very much divided as to the relation of the Devonian to the older rocks in South Devon and Cornwall, but [7] there is little doubt that a series of judiciously placed borings would solve the problem without difficulty. In North Devon and West Somerset, the question as to whether the Foreland Grits are a repetition by faulting of the Hangman Grits could also be settled at once by borings in the Hangman Grits and in the Lynton Beds.

In the North of England, again, there are many points where the strata exposed at the surface are low down in the Carboniferous, and it would be comparatively easy to ascertain the nature of the earlier rocks beneath them, with regard to which we are much in need of information.[8]

It would be easy to cite other cases where information of considerable geological value could be obtained by boring at comparatively small expense, and would in all probability in the majority of cases lead ultimately to results of economic importance.

It is obviously only right that any commercial advantages resulting from investigations carried out at the public cost should accrue to the State, and, if this principle were adopted, expenditure by the Government or geological research on the lines I have suggested would be sooner or later recouped by the mineral wealth rendered available to the community.

It is not, however, on terra firma alone that such investigations may be usefully carried out. The floors of the shallow seas that separate these islands from one another and from the continent of Europe are still almost unknown from the geological standpoint, although their investigation would present no

[7] I have already referred to the economic importance of this area. The desirability of ascertaining its true geological structure is too obvious to need emphasis here.

[8] The recent borings for mineral oil in the Carboniferous rocks of Derbyshire were put down largely by means of public funds, and such success as they have attained has been due to the fact that they were directed by expert geologists: but there can be little doubt that, if they had been carried out as part of a carefully-thought-out scheme of underground exploration wherever it was needed to elucidate the structure of the country, economies would have been effected and the sum total of our knowledge even from the economic standpoint would have been far greater. It is a pity that these borings have been carried out by means of the percussion process. It is, however, usually employed in borings for oil—in America almost exclusively—and in war-time its greater speed was no doubt an important factor in the decision to resort to it.

serious difficulties. Joly[9] has described an electrically driven apparatus which, when lowered so as to rest on a hard sea floor, will cut out and detach a cylindrical core of rock, and retain it till raised to the surface. Subsequently he invented a still more ingenious device[10], in which the force of the sea-water entering an empty vessel is substituted for electrical power, but unfortunately neither the one or the other has actually been tried or even constructed.

Meantime, however, vertical sections up to 80 cm. (2 ft. 7½ in.) of the mud of the deep seas have actually been obtained in iron tubes attached to sounding apparatus employed in the course of the voyage of the Gaussberg. These reveal a succession of deposits of which the lower usually indicate a colder climate than the upper, and have been referred for that reason to the last Glacial Period.[11]

In many places rock fragments are dredged up by fishing boats. These should of course be used with caution in drawing conclusions as to the distribution of rocks *in situ* on the sea bottom, as such fragments may have been transported when embedded in ice sheets or in ice bergs or other forms of floating ice, or entangled in the roots of floating trees; but where the rocks in question can be shown to have a definite distribution, as in those described by Grenville Cole and Thomas Crook from the Atlantic to the west of Ireland,[12] and by R. H. Worth from the western portion of the English Channel,[13] they may be regarded as affording trustworthy information as to the geology of the area.

There seems every reason to believe that advances in submarine geology will not be of only scientific interest, but will bring material benefits with them. Even at present the working of coal seams and metalliferous veins has been extended outwards beyond low-water mark, and, if evidence should be forthcoming that valuable deposits underlie the shallower waters of the North Sea at any point, there is no reason to doubt that mining engineers would find means of exploiting them. It seems quite possible that off the shores of Northumberland and Durham there are not only extensions of the neighbouring coalfield, but Permian rocks containing deposits of common salt, sulphate of calcium (gypsum and anhydrite), and, above all, potash salts comparable to those at Stassfurt, which have proved such a source of wealth to Germany.

No less important than the work of the Geological Survey is that of our great national museums. I have already alluded to the need for local collections to illustrate the geology of the areas in which they are situated. The museums of our larger cities and our universities will naturally contain collections of a more general character, but it is to our national museums that we must chiefly look for the provision of specimens to which those engaged in research can refer for comparison, and it is imperative that they should be maintained in the highest state of efficiency, if the best results are to be obtained from scientific investigations in this country. The ability and industry of the staff of the Mineralogical and Geological Departments of the National History Museum are everywhere recognised, as well as their readiness to assist all those who go to them for information, but in point of numbers they are undeniably insufficient to perform their primary task of examining, describing, arranging, and cataloguing their ever-increasing collections so as to enable scientific workers to refer to them under the most favourable conditions.[14] Even if the staff were

[9] 'On the Geological Investigation of Submarine Rocks,' *Sci. Proc. Roy. Dubl. Soc.*, vol. viii., pp. 509-524, 189.

[10] 'On the Investigation of the Deep Sea Deposits,' *Ibid.* vol. xiv. pp. 256-267, 1914.

[11] E. Philippi; 'Die Grund-proben der deutschen Sudpolar Expedition,' 1901-3, vol. ii., pp. 416-7 and 591-598.

[12] 'On Rock-specimens Dredged off the Coast of Ireland and their Bearing on Submarine Geology,' *Mem. Geol. Surv.*, Ireland, pp. 1-35, Dublin, 1910.

[13] 'The Dredgings of the Marine Biological Association' (1895-1906) as a contribution to the knowledge of the Geology of the English Channel.—*Journ. Marine Biol. Assoc.*, vol. viii., pp. 118-188. 1908.

[14] Even the number of skilled mechanics is quite insufficient, though their work is urgently needed. In the Geological Department provision is only made for two, and at present but one is actually at work.

doubled, its time would be fully occupied in carrying out these duties, quite apart from any special researches to which its members would naturally wish to devote themselves. The additional expense incurred by the urgently needed increase of the museum establishment would be more than repaid to the country in the increased facilities afforded for research.

There is room, too, for a considerable extension in the scope of the activity and usefulness of our museums in other directions, and more especially in the provision of typical lithological collections illustrating the geology of different parts of the British Empire and of foreign countries.

So far as the United Kingdom is concerned, this requirement has been admirably fulfilled in the museums attached to the Survey Headquarters in London, Edinburgh, and Dublin, and there is a smaller collection of the same nature, excellent in its way, at the Natural History Museum. But to obtain a broad outlook it is essential that the attention of geological workers should not be confined to one country, however diversified its rocks may be, and it is impossible to assimilate effectively publications dealing with the geology of other parts of the world without being able to refer to collections of the rocks, minerals, and fossils described.

The rocks, for instance, of the Dominion of South Africa are of the greatest scientific and economic interest, and many important communications have been published with regard to them. They present at the same time many features which distinguish them from European types, but I am not aware of any museum in this country where they are adequately illustrated.

Such collections should include not only rock specimens in the ordinary sense of the term, but also examples of metalliferous veins and other mineral deposits which present important distinctive features.

In the Imperial Institute there are at the present time collections from most of the different constituent parts of the British Empire, which fulfil to a certain extent these requirements, and they have been employed by myself and others in demonstrations to the Geologists' Association in illustration of the geology of Peninsular India and different parts of Africa; but they are very incomplete, having been collected with the view of exhibiting, not so much the character of the rocks and mode of occurrence of the minerals, not so much the character of the British Empire.

This is, of course, a function of the very greatest importance, but collections of minerals of intrinsic economic significance gathered together to assist in the development of the resources of the Empire should be organised on a different plan. They should be arranged, not according to the areas in which they occur, but with reference to the products obtained from them. The object of such collections is to enable those who are in want of materials for commercial purposes to ascertain where they can be obtained, and of what quality and at what price. For this purpose different samples of the same or similar ores or other products should be placed together irrespective of their origin, and each specimen should be accompanied by an assay or analysis, and such information with regard to its source and mode of occurrence as will enable the inquirer to form an opinion as to whether it will be likely to satisfy his requirements.

The lithological and palæontological collections which I am now advocating should, on the other hand, be arranged so that each group of specimens illustrates an area possessing distinctive geological features. Little has, hitherto, yet been done in this direction. The Mineral Department of the Natural History Museum possesses a large and extensive collection of foreign and colonial lithological specimens arranged according to localities, which is too little known, but it is naturally very unequal and incomplete, some countries being comparatively well represented and others scarcely at all. The Geological Department of the Museum is well provided with palæontological specimens, but these are arranged according to their biological affinities, and they might well be supplemented by a series of typical collections illustrating the fauna and flora of the more distinctive horizons in different areas. This is all the more important, as the mode of preservation may be very different in different places. It is probable that the geological surveys of British Dominions and Dependencies and of foreign countries would in many cases be able to supply such collections of rocks, mineral deposits, and fossils as I have suggested. Where

this is not possible, the only practicable means of obtaining really typical collections is to despatch a representative of the Museum, preferably one of its own officers, to make one himself. The provision of such facilities for the study of the geology of other lands is especially desirable in London in view of the number of students of mining and economic geology who receive their training in this country and ultimately go out into the world to find themselves face to face with problems in which a true understanding of the local geology is absolutely essential.

I shall not discuss here the important subjects of the indexing of geological literature and the preparation of abstracts of current publications. The former is already being efficiently dealt with by the Geological Society, and the latter will, I trust, be provided for in some way in the immediate future.

I now proceed to indicate some lines along which it seems to me probable that there are opportunities for progress in geological research.

In the investigation of the sedimentary rocks attention has been usually directed mainly to the larger and more obvious features, and these have sufficed to afford considerable insight into the conditions which prevailed when they were laid down. The detailed study of the minor structures or texture of these rocks by lens and microscope has, on the other hand, been comparatively neglected, though it is capable of affording us valuable information that could be obtained in no other way. There are, however, I need hardly say, important exceptions, the classical researches of Sorby extending over more than half a century, the investigations of Hutchings on the argillaceous rocks, and much useful work in recent years on the mineral constituents and microzoa of the sedimentary rocks generally. But, although individual sediments have been carefully studied, few, if any, attempts have been made to carry out a detailed examination of the successive beds of a stratigraphical succession comparable to the systematic zoning by means of fossils which has yielded such valuable results.

Not only ought the texture and composition of the individual laminæ to be patiently studied to obtain information as to the exact manner of their deposition, but attention should be more especially directed to the character of the transition by which one layer gives place to another, so as to determine, if possible, the cases where there has been a gradual passage without a break, and those in which there has been a pause in the deposition of greater or less duration, or even a removal of material, although nothing in the nature of an unconformity, however slight, can be detected. Even in apparently uniform deposits, such as chalk and clay, variations in texture and composition may be brought out by special treatment and reveal interesting details of the conditions under which they were deposited.

It is of special importance to recognise and examine in detail the occurrence of rhythmic repetitions of a similar succession of sedimentary materials and characters. A single cycle in such a succession may be only a twentieth of an inch in thickness, as in the case of ferruginous banding in the Lower Hangman Grits at Smith's Combe in the Quantocks, or may include thirty or forty feet of strata, as in the Caithness Flags. Rhythms have been described from the pre-Cambrian of Finland, the Ordovician of North America,[15] the Permian of Stassfurt,[16] the Cretaceous of Arkansas,[17] and the Quaternary of Scandinavia and Palestine, and many more, no doubt, occur in the stratigraphical succession of different countries. It would probably be found that a similar repetition occurs in fine terrigenous deposits off the coast of tropical countries where there is a well-defined alternation of wet and dry seasons. In some places minor cycles may be superimposed on larger, as in the case of the Skerry Belts described by Bernard Smith [18] in the Upper Keuper of East Nottinghamshire.

[15] Joseph Barrell; *Bull. Geol. Soc. Am.*, vol. xxviii., pp. 789-90, 1917.
[16] C. Ochsenius; *Zeitsch. für practische Geologie*. vol. 13, p. 168, 1905.
[17] G. K. Gilbert; *Journ. of Geology*, vol. iii., pp. 121-127.
[18] *Geol. Mag.*, 1910, pp. 303-305.

The general question of the significance of such rhythms of stratification must, however, be reserved for another occasion.

It is more difficult to arrive at the true interpretation of the phenomena presented by the endogenetic rocks[19] which have come into existence by the action of the forces of earth's interior, for the conditions of temperature and pressure under which they were formed, whether they are igneous rocks in the narrower sense, or mineral veins, or metamorphic in origin, were widely different from those with which we are familiar. Under such circumstances the ultimate physical principles are the same, but the so-called constants have to be determined afresh, and a new chemistry must be worked out. It is necessary, therefore, as far as possible, to reproduce the conditions that prevailed—a task which has been courageously undertaken and to a considerable extent accomplished by the Geophysical Laboratory of the Carnegie Institute at Washington.

By artificial means temperatures and pressures have been already produced far higher than those that were in all probability concerned in the evolution of any of the rocks that have been revealed to us at the surface by earth-movements and denudation, for it is unlikely that in any case they were formed at a greater depth than five or six miles, corresponding to a uniform (or, as it is sometimes termed, hydrostatic) pressure of 2,000 or 2,400 atmospheres, or at a greater temperature than 1,500° C. Indeed, it is probable that the vast majority of igneous and metamorphic rocks, as well as mineral veins, came into existence at considerably less depths, and at more moderate temperatures. It is true that most of the rock-forming minerals crystallise from their own melts at temperatures between 1,100° C. and 1,550° C., but they separate out from the complex magmas from which our igneous rocks were formed at lower temperatures, rarely much exceeding 1,200° C., and frequently considerably less.[20]

It has been found possible at the Geophysical Laboratory to maintain a temperature of 1,000° C. or more under a uniform pressure of 2,000 atmospheres for so long a time as may be desired, and, what is equally important, the temperature and pressure attained can be determined with satisfactory accuracy, the temperature within 2° C., and the pressure within 5 atmospheres.

It has been ascertained that such uniform pressure as would ordinarily be present at the depths mentioned does not directly affect the physical properties of minerals to anything like the same extent as the difference between the temperature prevailing at the earth's surface and even the lowest temperature at which igneous rocks can have been formed. It has, however, a most important indirect action in maintaining the concentration in the magma of a considerable proportion of water and other volatile constituents[21] which have a far-reaching influence in lowering the temperature at which the rock-forming minerals crystallise out, in other words, the temperature at which the rock consolidates, and in diminishing the molecular and molar viscosity of the magma, thus facilitating the growth of larger crystals and the formation of a rock of coarser grain. They must also be of profound significance in determining the minerals that separate out, the order of their formation, and the processes of differentiation in magmas.

It is, therefore, obvious that any conclusions derived from the early experiments which were carried out with dry melts at normal pressures must be received with very considerable caution. Nor does much advance appear to have been made, even at the Geophysical Laboratory, in experiments with melts containing large amounts of volatile fluxes, and yet, if we are to reproduce even approximately natural conditions, it is absolutely necessary to work with magmas containing a proportion of these constituents, and especially water, equal in

[19] T. Crook; *Min. Mag.*, vol. xvii., p. 87, 1914.

[20] It is probable that the temperatures recorded in some lavas higher than the melting point of copper, which is well over 1,200° C., are due to chemical reactions, such as the oxidation of hydrogen, carbon monoxide, ferrous oxide, and perhaps sulphur. See Day and Shepherd, *Bull. Geol. Soc. Amer.*, vol. xxiv., pp. 599-601, 1913.

[21] John Johnston, *Journ. Franklin Inst.*, Jan. 1917, pp. 14-19.

weight to at least one-third or one-half of the silica present. This will obviously present considerable difficulties, but there is no reason to doubt that it will be found possible to surmount them.

A much more formidable obstacle in realising the conditions under which rocks are formed is the small scale on which our operations can be carried on. There are important problems connected with the differentiation of magmas, whether in a completely fluid or partly crystallised state, under the action of gravitation, for the solution of which it would seem for this reason impossible to reproduce the conditions under which nature works. Instead of a reservoir many hundreds of feet in depth, we must content ourselves in our laboratory experiments with a vertical range of only a few inches. There are, however, other phenomena that require investigation and that involve a great difference of level in their operation, but do not take place at such elevated temperatures. Such are some of the processes of ore deposition or transference, especially secondary enrichment. Here, with the friendly assistance of mining engineers, but at the cost of considerable expenditure, it might even be possible to experiment with columns several thousand feet in vertical height.

In any attempt to reproduce the processes of metamorphism other than those of a purely thermal or pneumatolytic character, or to imitate the conditions that give rise to primary foliation, we must consider the effects of non-uniform or differential pressure involving stresses that operate in definite directions and result in deformation of the material on which they act. Unlike uniform pressure which usually raises the crystallisation point, differential pressure may lower it considerably and thus give rise to local fusion and subsequent recrystallisation of the rock.[21] At the same time it profoundly modifies the structure, resulting in folds and fractures of every degree of magnitude. One of the most pressing problems of geology at the present moment is to determine the effects of non-uniform pressure in its operation at different temperatures, and in the presence of different amounts of uniform pressure, a factor which has probably an important influence on the result, which must also depend on the proportion and nature of the volatile constituents which are present, as well as on the time during which the stresses are in operation. There seems no reason why valuable information should not be obtained on all those points by properly conducted experiments.

The time element in the constructive or transforming operations of nature cannot, of course, be adequately reproduced within the short space of individual human activity, or, it may be, that of our race; but I am inclined to think that, even in the case of metamorphic action, the importance of extremely prolonged action has been exaggerated.

In attempting to imitate the natural processes involved in the formation and alteration of rocks and mineral veins, we require some means of ascertaining when we have approximately reproduced the conditions which actually prevailed. It is not sufficient to bring about artificially the formation of a mineral occurring in the rocks or mineral deposits under investigation, for the same mineral can be reproduced in many ways. It is, however, probable that a mineral produced under different conditions is never identical in all its characters. Its habit, or the extent to which its possible faces are developed (a function of the surface tension), the characters of the faces which are present, its twinning, its internal structure, inclusions and impurities, all vary in different occurrences, and the more closely these can be reproduced, the greater the assurance we obtain that an artificial mineral has been formed under the same conditions as the natural product.

For this purpose it is above all necessary that there should be in the first place a systematic comparative study of these characters and of the association

[21] See J. Johnston and L. H. Adams, *Jour. Am. Chem. Soc.*, vol. xxxiv., p. 563 (1912); *Am. J. Sci.*, vol. xxxv., p. 206 (1913); A. Harker, *Proc. Geol. Soc.*, vol. lxxiv., pp. 75-77 (1919). It is interesting to note that similar principles apply to the pseudo-fluidity induced in clay by non-uniform pressure. See P. M. Crosthwaite, *Proc. Inst. C.E.*, December 19, 1916, p. 149; *Journ. and Trans. Soc. Eng.*, vol. x., pp. 82-86, 92-94; Alfred S. E. Ackermann, *ib.* pp. 37-80, 102-107.

in which they are found. The results thus obtained should be of the greatest value in indicating the directions along which experimental work would be most probably successful. They should, of course, be supplemented by laboratory studies of the relations of such subsidiary crystallographic characters to the environment in the case of crystals which can be formed under normal conditions of temperature and pressure, and therefore under the immediate observation of the experimenter. Some work has, in fact, already been done on the effects on these characters of the presence of other substances in the same solution.

In the study of the secondary alterations of metalliferous deposits, especially those which consist of the enrichment of mineral veins by the action of cirulating solutions, either of atmospheric or intratelluric origin, the study of pseudomorphs gives, of course, valuable assistance in determining the nature of the chemical and physical changes that have taken place.

A successful solution of the problem of the exact conditions under which deposits of economic importance are found would be of incalculable value in facilitating their discovery and exploitation, and would be the means of saving a vast amount of unnecessary labour and expense.

The problem of the structure and nature of the earth's interior, inaccessible to us even by boring, would seem at first sight to be well nigh insoluble, except as far as we can deduce from the dips and relations of the rocks at the surface their downward extension to considerable depths. We can, however, gain important information about the physical condition of the deeper portions from the reaction of the earth to the external forces to which it is subjected, and still more from a study of the 'preliminary' earthquake tremors that traverse it, the time occupied in their passage, and the difference in intensity of those that follow different paths. These methods are, however, not applicable to the earth's crust. Its physical characters appear to be distinct from those of the interior, but very little is as yet definitely known about them, except of course in the neighbourhood of the surface, and for this reason they are usually ignored in calculating the paths of tremors traversing the earth. It seems to be separated from the deeper portions of the earth by a surface of discontinuity at which earthquake vibrations travelling upwards towards the surface may be reflected. Calculations based on the total time taken by these reflected waves to reach the surface after a second passage through the earth's interior appear to indicate that this surface of discontinuity, whatever its nature may be, is at a depth of about twenty miles, though there can be little doubt that this depth varies considerably from point to point.

The main earthquake vibrations appear to follow the curvature of the earth, and to be confined to its crust, instead of traversing the interior, as is the case with the preliminary tremors. In these vibrations a period of about seventeen or eighteen seconds is usually predominant, and is believed to be due to the natural period of vibration of the earth's crust. Wiechert [22] assumes that there is a node halfway down and a free movement above and below, so that the full wave length would be twice the thickness of the earth's crust. Assuming a velocity of propagation of $3\frac{1}{2}$ km. per second, he calculates the depth of the crust to be approximately 30 km. There seems, however, to be no warrant for supposing that the lower surface of the crust is capable of free vibration. The fact that, not only waves of compression, but waves of distortion can traverse it shows that it must possess very high rigidity so far as forces of brief duration are concerned. The lower surface should therefore be regarded as a node, and only the upper as capable of free movement, so that the whole would correspond to a quarter of a wave length. On the other hand, the velocity of $3\frac{1}{2}$ km. per second, which is that of the propagation of waves round the earth's crust, in all probability a complex process, is not the same as the true velocity of vibrations passing upwards and downward through the earth's crust. Those with a period of about 18 seconds appear to consist partly of horizontal vibrations and partly of vertical; the former would seem to correspond to waves of distortion, and the

[22] *Göttingen Nachrichten*, 1907, pp. 468-9.

latter to waves of compression. The velocity of the former would probably be about 4 km. and the latter 7 km. per second, corresponding to the thicknesses of 18 km. and $31\frac{1}{2}$ km. (eleven and twenty miles). There is some evidence in the case of a distant earthquake of a period approximating to 30 km. per second, which would correspond, with waves of compression, to a thickness of 30 km. (nineteen miles). However in the present state of our knowledge of these vibrations such calculations are only of speculative interest.

There must be numerous surfaces of discontinuity in the earth's crust in addition to that forming its lower limit. Such would be the boundaries between great tracts of granite or granitoid gneiss and the basic rocks that in all probability everywhere underlie them; the surface dividing gneisses and crystalline schists from unmetamorphosed sediments overlying them unconformably; that between hard Palæozonic rocks and softer strata of later age; and the surfaces of massive limestones or sills. Wiechert observed at Göttingen, at the time of the Indian earthquake of April 4, 1905, small horizontal vibrations, superimposed on the others, with a period of only $1\frac{1}{2}$ seconds. He believed that these were due to horizontal distortional vibrations of the local sandstone formation with a node at its basal surface. He found the velocity of similar vibrations at the surface to be 250 m. per second, and thence calculated the depth of the sandstone stratum to be 90 m.[23] No doubt similar correlations of terrestrial vibrations and the structure of the earth's crust may be made in other cases.

It deserves consideration, however, as to how far it may be possible to add to our knowledge of the earth's crust by experimental work with a view of the determination of surfaces of discontinuity by their action in reflecting vibrations from artificial explosions, a procedure similar to that by means of which the presence of vessels at distance can be detected by the reflection of submarine sound waves. The ordinary seismographs are not suited for this purpose; the scale of their record, both of amplitude and of time, is too small for the minute and rapid vibrations which would be expected to reach an instrument situated several miles from an explosion, or to distinguish between direct vibrations and those that may arrive a second or two later after reflexion at a surface of discontinuity. As the cylinder on which the record is made would be only in motion while the experiment was in progress, there would be no difficulty in arranging for a much more rapid movement. At the same time it would be desirable to dispense with any arrangement for damping the swing of the pendulum, which would be unnecessary with small and rapid vibrations, and would tend to suppress them. It is possible that it might be better to employ a seismograph which records, like that devised by Galitzin shortly before his death, variations of pressure expressing terrestrial acceleration, instead of one which records directly the movements of the ground. It would, however, probably be found desirable to substitute for the piezo-electric record of pressure employed by Galitzin a record founded on the effect of pressure in varying the resistance in an electric circuit. This is, in fact, the principle of the microphone and most modern telephone receivers, but quantitatively they are very unreliable. This would not matter so much for the present purpose, where the time of transmission is the most important feature in the evidence, but satisfactory results even in this respect appear to be given by Brown's liquid microphone, from which the record could be taken, if desired, by means of the reflection of a mirror, attached to the needle of the galvanometer.

Evidence of the structure of the earth's crust is also afforded by observations on the direction and magnitude of gravitation which have been carried out in considerable detail in India and the United States—especially in the neighbourhood of great mountain ranges. At the present time the problem of correlating the variations observed with the underground structure is only in an embryonic stage. It is probable that our greatest hope of advancing researches with this object is by detailed work in areas which present no marked orographical features, and where the geological structure is already fairly well ascertained.

[23] *Ibid.* pp. 467-8.

The same remarks apply to the results obtained by magnetic surveys. Apart from the marked effect of masses of magnetite in the immediate neighbourhood of the surface, local magnetic irregularities appear to be mainly determined by the presence of basic igneous rocks,[24] but there seems to be considerable room for research as to the relation between these phenomena and the form and composition of an igneous intrusion.

In this review of some of the possibilities of geological research I cannot claim to have done more than touch the fringe of the subject. In every direction there is room for the development of fresh lines of investigation, as well as for renewed activity along paths already trodden. Whether my particular suggestions prove fruitful or not, they will have served their purpose if they have stimulated anyone to look for new fields of work.

Postscript.—Since this address was written, I have learnt that Professor Kendall has from time to time made valuable suggestions with regard to the association of the Survey with local workers, more especially the geological staff and students of our colleges.

[24] A. Hubert Cox : *Abstracts of the Proceedings of the Geological Society of London*, 1918, pp. 71-74.

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ADDRESS

TO THE

ZOOLOGICAL SECTION

BY

DR. F. A. DIXEY, M.A., F.R.S.,

PRESIDENT OF THE SECTION.

ONE of the results of the great war now happily at an end has been its effect upon science. On the one hand it has checked the progress of scientific investigation; it has done much to destroy international co-operation and sympathy; it has removed from our ranks, temporarily or permanently, many admirable workers. On the other hand it has acted as a great stimulus in many departments of scientific inquiry, and it has given the general public an interest in many scientific questions which have hitherto met with little recognition or encouragement from the people at large. It was perhaps inevitable, but at the same time, as I venture to think, rather to be deplored, that that interest has tended to concentrate itself upon applied more than upon abstract science; that it has been concerned chiefly with the employment of natural knowledge in devising and perfecting new methods of destruction. Terrible as is the power which the present-day engines of warfare have attained, it may be reasonable to hope that some compensation for the mischief and suffering which they have caused may eventually be found in peaceful directions; that the submarine, the air-craft, and even the high explosive may cease to be a terror to civilisation, and in spite of their past history may after all become agents in the advancement of the general welfare :

Hoc paces habuere bonae, ventique secundi,

will, let us hope, be a legitimate reflection in later times. But for the true scientific worker, I think I may safely assert, the primary object of his studies is the attainment of knowledge for its own sake : applications of such knowledge may be trusted to follow; some beneficial, some perhaps the reverse. Still, whether they do or do not so follow is less a concern of the scientific man than whether his labours have resulted in a fresh advance into the realms of the unknown. I confess to some sympathy with the feeling which is said to be expressed in the regular toast of a certain scientific gathering :—' Pure mathematics, and may they never be of any use to anybody.'

For genuine enthusiasm in the cause of science for its own sake, I think that we zoologists may claim a good record. We are by no means unmindful of the great benefits to humanity which have taken their rise more or less directly from zoological science. I need do no more than mention the services to medicine, great at the present and destined to be greater still in the future, that are being rendered by the protozoologist and the entomologist. We may look forward also to results of the highest practical importance from the investigations into the laws of heredity in which we are engaged with the co-operation

of our allies the botanists. But what we are entitled to protest against is the temper of mind which values science only for the material benefits that may be got from it; and what above all we should like to see is a greater respect on the part of the public for science purely as science, a higher appreciation of the labours of scientific men, and a greater readiness, in matters where science touches on the common affairs of life, to be guided by the accumulated knowledge and experience of those who have made such matters the subject of constant and devoted study. If the war leads to any repair of the general deficiency in these respects, it will to that extent have conferred a benefit on the community.

Regarding, as I do, my present position in this Section as a great honour and privilege, especially in view of this being the first meeting of the British Association to be held after the war, I hope I may be allowed a few preliminary remarks of a somewhat autobiographical character. As far back as I can remember, zoology has been a passion with me. I was brought up in a non-zoological environment, and for the first few years of my life my only knowledge of the subject was gained from an odd volume of Chambers's 'Information for the People.' But on being asked by a visitor what I intended to do with myself when I grew up, I can distinctly remember answering, with the confident assurance of seven or eight, 'Zoology suits me best'—pronouncing the word, which I had only seen and never heard, as *zoo*logy. By the time I went to school, my opportunities had increased, but I soon found myself engaged in the classical and mathematical routine from which in those days there was little chance of escape. In due course I went to the University with a classical scholarship, which necessitated for the time an even more rigid exclusion of scientific aspirations than before. I mention this because I wish to pay a tribute of gratitude to the College authorities of that day, to whose wise policy I owe it that I was eventually able to fulfil in some measure my desire for natural, and especially biological, knowledge. After two years of more or less successful application to the literary studies of the University, I petitioned to be allowed to read for the final school in natural science. The petition was granted; my scholarship was not taken away, and was even prolonged to the end of my fifth year. This I think was an enlightened measure, remarkable for the time, more than forty years ago, when it was adopted. I only hope that we have not in this respect fallen back from the standard of our predecessors. The avidity with which I took up the study of elementary chemistry and physics, and the enthusiasm with which I started on comparative anatomy under the auspices of George Rolleston are among the most pleasant recollections of my youth. But from the force of circumstances, though always at heart a zoologist, I have never been in a position to give myself unreservedly to that department of biology; and even now, in what I must call my old age, I fear I cannot regard myself as much more than a zoological amateur. My working hours are largely taken up with serving tables.

What moral do I draw from this brief recital? Not by any means that I should have been allowed to escape a grounding in the elements of a literary education, though I think it quite possible that the past, and even the present methods of school instruction are not ideally the best. My experience has led me to conclude that much of the time spent over the minutiae of Greek and Latin grammar might, in the case of the average boy, be better employed. But I do not agree that a moderate knowledge of the classics, well taught by a sensible master, is useless from any reasonable point of view. To those of my hearers who appreciate Kipling, I would call to mind the vividly truthful sketch of school life called 'Regulus.' Let them reflect how the wonderful workmanship of the inspired and inspiring Ode of Horace, round which the sketch is written, must have sunk into the mind of the apparently careless and exasperating 'Beetle,' the 'egregious Beetle' as King calls him, to bear such marvellous fruit in after years. Beetle, as we all know, is no professional scholar, no classical pedant, but a man of the world who has not forgotten his Horace, and upon whose extraordinary literary skill those early school-tasks must have had, whether consciously or not, a dominating influence. How else could he have written 'Regulus'? 'You see,' says King, 'that some of it sticks.' So it does, if it is only given a fair chance; and in the skirmish between King the classical and Hartopp the science master, both right up to a point and both wrong beyond it, I give on the whole the palm to King. To

revert to my own case. I do not regret a word of either the Latin or the Greek that I was obliged to read, nor even the inkling of the niceties of scholarship to which I got, I hope, a fair introduction. But I do think that I might have been allowed to start on scientific work at an earlier period, and that a good deal of the time spent, say, on Greek and Latin prose and verse writing, might in my case have been well spared for other objects.

To generalise what I have been saying. Start teaching your boy or girl on a good wide basis. Nothing is better for this than the old school subjects of classics, history and mathematics, with the addition of natural science. In course of time a bent will declare itself. Encourage this, even at the expense of other studies desirable in themselves. But do not allow any one subject, however congenial, to usurp the place of a grounding in those matters which are proper to a general education. The time for specialising will come; and when it has arrived do all you can to remove obstacles, pecuniary and other. Do not hamper your historian with chemistry or your zoologist with the differential calculus. If they have a taste for these things by way of diversion or recreation, well and good. But let their action be voluntary.

This, however, is not a fitting occasion for propounding my views on the question of education, and it is time to turn to the immediate object of my address. And here I think I cannot do better than to bring before your notice certain facts which have a bearing on the subject of insect mimicry; a subject which for many years past has engaged much of my attention. The facts on all hands are allowed to be remarkable. As to their interpretation there is much diversity of opinion; and indeed, until complete data are forthcoming, this could hardly be otherwise.

In the first place let us glance at a certain assemblage of butterflies that inhabits New Guinea with some of the adjacent islands. These butterflies, though belonging to different subfamilies, present a resemblance to each other which is too strong to be accidental. Three of them belong to the Pierines, the group which includes the common white butterflies of this country; the fourth is a Nymphaline, not widely removed from our well-known tortoiseshells, red admiral and peacock. The resemblance on the upper surface between two of the three Pierines is not especially noteworthy, inasmuch as they present in common the ordinary Pierine appearance of a white or nearly white ground colour with a dark border somewhat broadened at the apex. But this, an everyday feature in the Pierines, is almost unknown in the very large subfamily to which our present Nymphaline belongs. Still, though sufficiently remarkable to arrest the attention of anyone familiar with these groups, the Pierine-like aspect of the upper surface of this Nymphaline, which is known as *Mynes doryca,* would not by itself have seemed to call for any special explanation. The resemblance would pass as merely an interesting coincidence. But the under surface of the three Pierines, known respectively as *Huphina abnormis*, *Delias ornytion* and *Delias irma*, presents a striking combination of colour very unusual in their own group; and this peculiar character of the under surface is shared by the Nymphaline *Mynes doryca*. The 'long arm of coincidence' could scarcely reach as far as this. Whatever might be said about the likeness seen from above, that the wings beneath should show virtually the same unusual pattern in the *Mynes* as in the Pierines seems to call for some explanation other than an appeal to chance or accident. Moreover, with regard to the Pierines themselves, the two members of the genus *Delias* are of course fairly closely related; but the *Huphina* belongs to an entirely distinct genus, separated from *Delias* by many important structural differences. The two species of *Delias* perhaps depart less widely in aspect from their nearest congeners than does either the *Huphina* or the *Mynes*. The under surface of the *Huphina* is unexampled in its genus, but the upper surface is quite ordinary. The *Mynes*, as we have seen, stands alone among its nearest relatives not only in the character of its under surface, but also in the Pierine-like character of its wings above.

We will now turn to another assemblage, which presents us with the same problem from a somewhat different point of view. In south-eastern Asia, with certain of the adjacent islands, is found a genus of large butterflies, called by Wallace *Prioneris* from the saw-like front margin of the forewing in the male. More than fifty years ago it was remarked by Wallace that the species of *Prioneris*

in several cases seem to mimic those of the genus *Delias*, and that 'in all cases the pairs which resemble each other inhabit the same district, and very often are known to come from the same locality.' The parallelism is even stronger than was stated by Wallace, for there is not a single known member of the genus *Prioneris* which does not resemble a species of *Delias*, so that *Prioneris* cannot really be said to have an aspect of its own. *Prioneris clemanthe* and *Delias agostina* form a pair inhabiting the Himalayas, Burma and Further India. In the same region occur *Prioneris thestylis* and *Delias belladonna*, the striking similarity of which species, especially on the underside and in the female, drew the special attention of Mr. Wallace. A still more remarkable instance is that of *Prioneris sita* of southern India and Ceylon, the likeness of which to the common Indian *Delias eucharis* is spoken of by Wallace as 'perfect'; while Fruhstorfer, a hostile witness, testifies to the fact that the *Prioneris* always flies in company with the *Delias*, and rests just like the latter with closed wings on the red flowers of the Lantana. *Prioneris hypsipyle* of Sumatra and *P. autothisbe* of Java are like *Delias egialea* and *D. crithoe* of the same two islands. Here again Fruhstorfer says of *Prioneris autothisbe*, that it visits the flowers of the Cinchona, 'always in company with the similarly coloured *Delias crithoe*.' Wallace remarked on the close similarity between *Prioneris cornelia* of Borneo and *Delias singhapura* of the Malay Peninsula; in this case, it will be noted, the localities though not far distant from each other, are not identical. But a *Delias* form which was unknown at the date of Wallace's paper has since been found in Borneo, and this latter butterfly, known as *D. indistincta*, is even more exactly copied by *P. cornelia* than is the *Delias* which first drew Wallace's attention. *Prioneris vollenhovii* of Borneo is a kind of compromise between *Delias indistincta* and, on the underside, *D. pandemia* of the same island, and it may be added that another Bornean Pierine, *Huphina pactolica*, is a good copy of *Delias indistincta*, therefore resembling also the Bornean *Prioneris cornelia* and *P. vollenhovii*.

The memoir, published in 1867, in which Wallace remarked on the parallelism between *Prioneris* and *Delias*, contains a noteworthy prediction by the same author. Speaking of *Pieris* (now called *Huphina*) *laeta* of Timor he says that it 'departs so much from the style of colouring of its allies and approaches so nearly to that of *Thyca* (*Delias*) *belisama* of Java, that I should almost look for an ally of the last species to be discovered in Timor to serve as its pattern.' Thirty-four years after the expression of this anticipation, Mr. Doherty discovered in Timor an ally of *Delias belisama* which at once suggests itself as the model from which the peculiar and brilliant colouring of *Huphina laeta* has been derived. Fruhstorfer, who is by no means friendly to the theory of mimicry, says of this *Delias*, which was named *splendida* by Lord Rothschild, that beneath it is 'deceptively like *Huphina laeta*.' But here comes in a curious point. The black forewing with its yellow apex and the orange-yellow hindwing with its scarlet black-bordered costal streak are present on the underside of both the *Delias* and the *Huphina*; but the latter butterfly possesses in addition to these features a row of scarlet marginal spots on the hindwing which are not to be found on the *Delias*. In spite of this discrepancy, the likeness is sufficiently striking. But from the same island of Timor, Doherty sent home another *Delias* which besides resembling *D. splendida*, possesses a row of scarlet patches in the corresponding situation to those of *H. laeta*. In this latter *Delias*, however, named *dohertyi* by Lord Rothschild after its discoverer, the brilliant scarlet costal streak is completely absent. The *Huphina*, therefore, is more like either species of *Delias* than they are like each other, forming, as it were, a link between them. So that, adopting Professor Poulton's terminology, we may say that, if this is a case of mimicry, one form may possess at the same time the aposemes belonging to two distinct models. I will not now stop to discuss the bearing of this case on current theories, but will only remark that, granting mimicry, the whole assemblage, *D. splendida*, *H. laeta*, *D. dohertyi*, may be expected to gain advantage from the blending action of the intermediate *H. laeta*. This I think would happen whether *laeta* is a 'Batesian' or 'Müllerian' mimic, but the gain to the association in the latter case is certainly the more obvious.

This state of things would be sufficiently curious if it stood by itself. But it

does not stand by itself. In Lombok, Sumbawa and Flores there occurs another member of the peculiar group of *Huphina* to which *H. laeta* belongs. This butterfly, known as *H. temena*, resembles *H. laeta* in many respects; possessing on the underside of the hindwing a scarlet costal streak and a row of scarlet marginal spots like those of that insect. The forewing, however, differs from that of *H. laeta* in having its ground-colour not uniformly black, but divided between a dark shading to the veins, a dark submarginal band, and series of pale streaks and patches in the interspaces between the veins. The question at once suggests itself: Is there a relation between *H. temena* and one or more species of *Delias* corresponding to that between *H. laeta* and *D. splendida* and *dohertyi*? The answer to this question is in the affirmative. *Delias oraia*, together with *Delias sumbawana*, both species inhabiting the same three islands as *H. temena*, form with it an assemblage quite comparable with the former triad from Timor. Further, the points in which *H. temena* differs from *H. laeta* have their counterpart in the distinctions between *D. oraia* and *D. splendida* on the one hand, and *D. sumbawana* and *D. dohertyi* on the other. These points are chiefly, in the *temena* assemblage, the less definitely black-bordered costal streak, the more strongly-marked black bordering to the submarginal scarlet spots, and the diversely-coloured as compared with the uniformly black forewing of the Timor insects.

Again, in the island of Bali, *Huphina tamar* would seem to combine certain features of two species of *Delias* in a similar manner to the cases of *laeta* and *temena* just considered. The underside as a whole is reminiscent of *D. periboea*, a member, like *D. dohertyi* and *D. sumbawana*, of the *eucharis* or *hyparete* group of the genus; while the red costal streak suggests the influence of a representative in Bali of the *belisama* group, like *D. splendida* and *D. oraia* in the other islands.

Finally, in the island of Sumba we have another member of this remarkable group of *Huphinas*. *Huphina julia*, the butterfly referred to, so closely resembles *Delias fasciata* of the same island, that even the sceptical Fruhstorfer is constrained to speak of it as a 'faithful copy' of that insect. But here once more it is noticeable that one of the most conspicuous features of the *Huphina* is absent from the *Delias*. This time it is not, as in the case of *D. splendida*, the submarginal row of scarlet spots on the underside of the hindwing, but it is the scarlet costal streak that is wanting. *Huphina julia* was discovered by Mr. Doherty in the year 1887, and described in 1891. It is interesting, in the light of what is now known of the butterfly fauna of the Lesser Sunda islands, to read what Doherty has to say about the mimicry question in relation to the *Delias* and *Huphina* forms that have just been mentioned. Speaking of *H. julia*, he says, 'If it stood alone, I should certainly suppose it to be a mimic of some form of *Delias hyparete* yet undiscovered in the island. But both *H. laeta* and *H. temena* require to be accounted for in the same way, and while it is possible that some Timorese *Delias* may resemble *H. laeta*, I feel sure that *H. temena* can have no such original. It must then be assumed that this group is less pressed by its enemies in the Timorian Islands, and has therefore been able to acquire more brilliant colours than its allies.' So far Doherty.

Whatever may be the value of this last hypothesis, we have just seen that the supposed facts on which it rests are non-existent, for (1) the 'form of *Delias hyparete* as yet undiscovered' has actually turned up in the person of *D. fasciata*; (2) it is not only possible, but actually the case that 'some Timorese *Delias* may resemble *H. laeta*'; (3) Mr. Doherty 'feels sure that *H. temena* can have no such original,' but *Delias oraia* and *Delias sumbawana* have just the same relation to *Huphina temena* as *D. splendida* and *D. dohertyi* to *H. laeta*. In view of these facts it may be not rash to suppose that the apparent absence of a model for the red costal streak of *H. julia* may hereafter be accounted for.

Of the three instances of possible mimetic association which have now been mentioned, I think that only one—*viz.*, the first, has previously been treated in detail. The numbers of cases more or less similar to these three might be very largely extended, but for our present purpose it will be sufficient to confine our attention to those already given. It is probable that to some minds the facts adduced are simply curious coincidences, needing no explanation: but it can hardly be wrong to suppose that to most students of nature the observed

phenomena do call for some attempt at interpretation; and on a review of the evidence it seems clear that the geographical element must enter largely into any explanation that may be offered. On the whole, it is certainly the case that the forms which are supposed to be related by mimicry do inhabit the same localities; the continental *Prioneris*, for example, is like the continental *Delias*, and the island *Prioneris* recalls the island, not the continental, *Delias*. Moreover, we find the differences between the *Delias* of Timor, of Sumbawa and Sumba, reflected in the associated *Huphinas* of the same islands. If it be granted that the geographical element is a factor, it is natural to inquire how it works.

It is no doubt true that external geographical conditions are occasionally capable of producing, whether directly or indirectly, a community of aspect in the animals or plants exposed to their influence. The prevalence of a sandy coloration in the mammals and birds of a desert, and of whiteness in the inhabitants of the arctic snow-fields, the spiny character so often assumed by the plants of arid regions, and the general dwarfing of the vegetation that grows close to the sea, may be given in illustration. At first sight these phenomena may seem to be of the nature of direct effects of the environment; quite possibly some of them are so, but I think that few observers would deny that they are at least largely adaptive, being used for purposes of aggression or defence. Still, even if we allow the direct effect of the environment, as perhaps we may do especially in the case of the plants, can we frame any hypothesis of the action of geographical conditions which shall lead directly to the assumption of a common pattern in the case of the three or four butterflies from New Guinea? I confess that I am quite unable to do so. If the climate, or the soil, or any other geographical condition in New Guinea is capable of directly inducing so remarkable a combination of colour as we see in these Pierines and Nymphaline, why does it not affect other organisms in a similar way? Why do not other Pierines, for instance, closely related to *ornytion* and *abnormis*, share in the same coloration? And considering the characteristic aspect of the underside, which is supposed to be called into being by some unexplained condition peculiar to New Guinea, we may well ask, Why should its most conspicuous features belong in the one case to the forewing and in the other to the hindwing, and *vice versâ*, the general effect being the same?

Fruhstorfer, we may note, does not feel these difficulties. 'Many Pierids,' he says, 'present typical examples of that resemblance to other butterflies which has been named Mimicry. The origin of this resemblance, however, is now explained by the supposition that the mimics were modified by the same (as yet unknown) influences under which the colouring of the models, mostly Danaids, developed.' I think it will be generally agreed that this reference to 'unknown influences' is no explanation at all.

It is necessary to take into account the fact that the resemblances of which we are speaking are independent of structural differences, being, in fact, merely superficial. This is a point which is capable of much wider demonstration than I am giving it to-day. But even from the instances now before us I think there cannot be much difficulty in coming to the conclusion that the resemblances are an appeal to vision. They are meant to be *seen*, though by whom and for what purpose may be open to question. Speculations as to recognition and sexual attraction may, I think, in these cases be put out of court; but there remains the theory of warning colours assumed in reference to the attacks of vertebrate enemies. From the fact that the most striking and most conspicuous of these common aposemes or danger-signals belong to the under surface—that is to say, the part chiefly exposed to view during rest—it may be inferred that the enemies to be guarded against are mainly those that attack butterflies not on the wing, but when settled in repose. Both birds and monkeys are known to feed on butterflies, and there is a good deal of evidence as to their preference for one kind of food over another. I will not stop to give details, but anyone who wishes to study the evidence may be referred especially to the Memoirs of Dr. G. A. K. Marshall and Mr. C. F. M. Swynnerton.

If the warning-colour interpretation of these resemblances be the true one, we see at once why they are so largely independent of structure and affinity. Being meant to catch the eye, they ride rough-shod, so to speak, over incon-

spicuous features, such as venation; nor do they respect more than the nature of things obliges them to do, the ties of blood-relationship. Then, again, it is obvious why they occur in the same and not widely different localities; in some instances, as we have seen, their bearers actually flying in company and frequenting the same flowers; for the common aspect, supposing it to be in any sense protective, would only take effect when the sharers in it were exposed to the attacks of the same body of enemies; that is to say, when they inhabited the same locality. And this would be equally true, whether the warning colours are shared between distasteful forms, or whether they are deceptively adopted by forms unprotected by inedibility;—whether, in Professor Poulton's terms, they are synaposematic or pseudaposematic. I do not enlarge upon this part of the question, or upon the theories which are known under the names of Bates and Müller respectively, because these theories have been fully dealt with elsewhere, and I think I may assume that they are familiar to the greater part of my hearers. But that mistaken ideas as to what is really meant by protection and mimicry still prevail in some quarters, is evident from certain remarks of Fruhstorfer in dealing with the genus *Prioneris* which we have just been discussing. 'Wallace,' he says, 'regards the "rarer" *Prioneris* as a mimetic form of the "commoner" *Delias*. But I cannot accept his view, since mimicry among the in all respects harmless Pierids appears no sort of protection, and properly speaking the smooth-margined *Delias* should rather copy the armed *Prioneris* if there is assumed to be mimicry at all.' If anyone has no better knowledge than this of what is meant by the theory of mimicry, it is not wonderful that he should consider the subject unworthy of serious attention.

The warning-colour theory, then, gives a rational explanation both of the superficial character of the resemblances and of the geographical factor in their occurrence. But it obviously involves the reality of natural selection; and it is here that some are disposed to part company with the upholders of the theory. I have already referred to the fact that much positive evidence now exists both that butterflies are eaten and that preferences on the part of their enemies exist between one kind and another. I will only remark in passing that the objector on this score sometimes adopts an attitude which is scarcely reasonable, and which perhaps on that very account is somewhat hard to combat. The kind of objector that I mean begins by saying that the destruction of butterflies by birds and other enemies is not sufficient to give play for the operation of selection. You beg his pardon, and produce evidence of considerable butterfly destruction. To which he replies, 'O, they *are* eaten, are they? I thought you said they were protected.' This is a good dilemma, but the dilemma is notoriously an unconvincing form of argument. If a reply be called for it may be given like this: 'Butterflies are either preyed upon or they are not. If they are, an opening is given for selection; if they are not, it shows the existence of some form of protection.' The essence of the matter is that both the likes and dislikes of insectivorous animals, and the means of protection enjoyed by their prey, are not absolute but relative. A bird that will reject an insect under some circumstances will capture it under some others; it will, for instance, avoid insect 'A' if it can get insect 'B,' but will feed on 'A' if nothing else is to be had; and it is probable that hardly any insect is entirely proof against the attack of every kind of enemy. The relative nature of protection is readily admitted when the question is not one of mimicry or of warning colours, but of protective resemblance to inanimate objects. All degrees of disguise, from the rudimentary to the almost perfect, are employed; the lower degrees are allowed to be of some service, and on the other hand a disguise that is almost completely deceptive may at times be penetrated. This consideration applies also to the objection that the first beginnings of mimetic assimilation can have no selective value. If the rough resemblance to an inanimate object affords some amount of protection, though that amount may be relatively small, why should not the same apply to the first suggestion on the part of a mimic of an approach to the aposeme or warning colour of its model? The position that neither kind of assimilation is of service is intelligible, though not common; but there is no reason why benefit should be affirmed in the one case and denied in the other. There are further considerations which tend to deprive this latter criticism of force; the fact, for instance, that a resemblance to one

form may serve as a stepping-stone for a likeness to another; or, again, the existence of clusters, as they may be called, of forms varying in affinity, but embodying a transition by easy stages from one extreme to another. In a case of this sort the objection that may be felt as to two terms in the series arbitrarily or accidentally picked out is seen to be groundless when the whole assemblage is taken together.

Much attention has lately been given to the fact that of individual variations some are transmissible by heredity and some are not; under the latter heading would generally fall somatic modifications directly induced upon the individual by conditions of environment. Whether any other kind of variation belongs to the same category need not for the present purpose come into discussion. But with regard to the undoubtedly transmissible variations, or mutations if we like to call them so, there is, I think, a fairly general consensus of opinion that they need not necessarily be large in amount. A complete gradation in fact appears to exist between a departure from type so slight as to be scarcely noticeable and one so striking as to rank as a sport or a monstrosity. And we know now that where the Mendelian relation exists between two forms, no amount of interbreeding will abolish either type; intermediates, if formed, are not permanent, and if one type is to prevail over the other it must be by means of selection, either natural or artificial.

In view of all these considerations I venture to think that there is no reason to dispute the influence of natural selection in the production of these remarkable resemblances. Other interpretations may no doubt be given, but they involve the ignoring of some one or more of the facts. It may fairly be claimed that the theories of Wallace, Bates and Müller, depending as they do on a basis of both observation and experiment, come nearer to accounting for the facts than any other explanation as yet offered. It will of course always be possible to deny that any explanation is attainable, or to assert that we ought to be satisfied with the facts as we find them without attempting to unravel their causes. But such an attitude of mind is not scientific, and if carried into other matters would tend to deprive the study of nature of what to most of us is its principal charm. It is quite true that before the validity of any generalisation is accepted as finally and absolutely established, every opportunity should be taken of deductive verification. This has been fully recognised by the supporters of the theory of mimicry, and much has been done to test in this manner the various conclusions on which the theory rests. The verification is not complete, and perhaps never will be, but every successive step increases the probability of its truth; and probability, as Bishop Butler taught, is the guide of life. Meantime it is, one may say, the positive duty of everyone who has the opportunity, to fill up, so far as is in his power, the gaps that still exist in the chain of evidence. Here is an especially promising field for naturalists resident in tropical regions.

Before concluding this address, there are two points on which I should like to lay some special emphasis. One is the undesirability—I had almost said folly—of undervaluing any source of information, or any particular department of study, which does not come within the personal purview of the critic or commentator. 'I hold,' says Quiller-Couch, 'there is no surer sign of intellectual ill-breeding than to speak, even to feel, slightingly of any knowledge oneself does not happen to possess.' This is a temptation to which many of us are liable; and falls, I fear, are frequent. It was a matter of sincere regret to me to find one of my most valued scientific friends speaking publicly of the Odes of Horace as a subject comparatively devoid of interest. I can only confess my utter inability to sympathise with my friend's point of view. If he had merely said, 'excellent as those works may be, I have other things to do than to attend to them,' I could approve; but that is a different matter. The failing that I speak of is unfortunately by no means unknown among scientific men, and is perhaps rather specially prevalent when such subjects as those of my present address are in question. I can recall a very eminent man of science, no longer living, speaking with scarcely veiled scorn of those who occupied themselves with 'butterflies in cases.' This was in a Presidential Address to a Section of this Association. If so little respect is paid by a leader of science to work done in another part of the field, it is perhaps not to be wondered at

that one of His Majesty's Judges should speak of the formation of a great collection of butterflies—a most valuable asset for bionomic research—as the 'gratification of an infantile taste.' This or that collector may be an unscientific person, but it would be easy to show that the study of insects in general, and of butterflies in particular, is one of the most efficient of the instruments in our hands for arriving at a solution of fundamental problems in biology.

My second and final point is this. I have not hesitated to affirm my conviction of the importance in evolution of the Darwinian doctrine of natural selection. This necessarily carries with it a belief in the existence and general prevalence of adaptation. I am willing to admit that at times too much exuberance may have been shown in the pursuit of what Aubrey Moore called 'the new teleology.' 'Men of science,' it has been said, 'like young colts in a fresh pasture, are apt to be exhilarated on being turned into a new field of inquiry; to go off at a hand-gallop, in total disregard of hedges and ditches, to lose sight of the real limitation of their inquiries, and to forget the extreme imperfection of what is really known.' This is not the utterance of some cold outside critic, but of a great exponent of scientific method—no other than Huxley himself. It may be true of some of the wilder speculations of Huxley's date. I am by no means sure that there is not truth in it as applied to some of the developments of a later time. But however wide of the mark our suggested explanations and hypotheses may be, the net result of all our inquiries, after the gradual pruning away of excrescences and superfluities, will be a real advance into the realms of the unknown. We may feel perfectly assured that the objections so far brought against our own interpretations are null and void, but we may yet have to give way in the light of further knowledge. 'Let us not smile too soon at the pranks of Puck among the critics; it is more prudent to move apart and feel gently whether that sleek nose with fair large ears, may not have been slipped upon our own shoulders.'[1]

[1] Dowden.

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ADDRESS

TO THE

GEOGRAPHICAL SECTION

BY

PROFESSOR L. W. LYDE, M.A.,

PRESIDENT OF THE SECTION.

The International Rivers of Europe.

THIS subject was chosen before the publication of the Treaty of Peace, and was dictated by a wish to combine my geographical creed with the political conditions of an 'Americanised' Europe. The Treaty embodies so many of the principles which I wished to emphasise, that my treatment should perhaps now be rather historical than political.

My geographical faith is in Outlook; the jargon of to-day is about Leagues of Nations. This is the day of nations and nationalities, and geographers must rejoice in the fact, because civilisation depends on a blend of varied influences—each an individual element, a *genius loci*—and the triumph of nationality must curb that tendency to a drab cosmopolitanism which would crush out all such variety. But these varied influences cannot blend into a progressive civilisation unless they have all possible facilities for friendly meeting; for instance, International Rivers should not be, like International Finance, anti-national, but really inter-national, 'between nations,' common to all nations, and encouraging the friendly meeting of diverse political elements and ideas. Liberty always makes for differentiation—in nations as in individuals; and if our international intercourse becomes really 'free' the desired variety is guaranteed.

This is why I would like to press the truth that Outlook is, or ought to be, the motto of geography. It is so for many of us, and it ought to be for all. But the word covers both a process and an objective. The Outlook is essentially over Big Mother Earth; the process is visualisation—the picturing of forms and forces, places and peoples, beyond the horizon, all possible horizons being included in the one great unit of the globe. But the geographical interaction of the Man and the Place cannot be dissociated—least of all in Political Geography—from the historical interdependence of group and group. Both alike are concerned with progress. We want to know, therefore, the whole simple truth—what the particular features and phenomena mean as world features and world phenomena, *not* what special meaning can be read into them, or extracted from them, by some local and interested political unit. Geography is, first of all, the visualisation of the world and the relations of the various parts of that world.

Now, the one predominant feature of the earth's surface is not land, but water. Nearly all international problems to-day have to do, explicitly or implicitly, with the ocean, *i.e.* with access to cheap water transport on the medium which covers three-quarters of the whole surface of the earth. Even the problem of Alsace-Lorraine, itself perhaps purely a land problem, conceals—especially from the Swiss point of view—a problem of access to the sea; and the problems of Poland, of Italy, of Jugoslavia, are obviously sea-problems or sea-problems very slightly disguised.

It is a truism that the ocean attracts rivers and their trade and their riverine population. Industry, commerce, even culture, have been starved and stunted in various parts of the world by lack of easy access to the sea. Even your League of Nations idea has more than once approximated to a substantial fact—round the Mediterannean and round the Baltic, facilitated by inter-national or inter-racial rivers. The Hanseatic League was essentially based on the relation of a number of more or less navigable rivers to an inland sea, and that was why it came to include such distant 'inland' members as Breslau and Cracow.

Accessibility is now more than ever before a supreme factor in all cultural and economic development, and rivers are still the chief natural intermediaries between land and sea. The first real international attempt to solve the problem of international rivers followed the victory of Sea Power over the France of Napoleon the Great; the second has followed the victory of Sea Power over this would-be 'Napoleon' of Prussia.

Now, I submit that to many of us the mere word *river* by itself suggests, at once and primarily, a physical unity—no doubt, with some variety of relief and climate—and that on this physical unity we are prepared to sanction some social and economic and even political unity. But directly you add the qualifying *international*, the suggestion changes; the adjective raises a picture not of local features, but of regional relations.

In recent years I have pleaded for the use of rivers as political boundaries—on the ground that they clearly separate lands without at all separating peoples except in time of war; we want to preserve the valuable variety of political and cultured units, but to draw the various units together. Our object is unity, not uniformity. The proposal has been objected to—even by some who are not at heart hostile to the idea of fostering all possible aids to the easy, honourable, friendly intercourse of peoples—on the ground that rivers shift their courses. They do, and trouble has come of this in the past, political trouble as well as economic. The Missouri was a fertile source of Inter-State squabbles. But no normal person would *choose* a mud-carrier, like the Missouri, 'Muddy Water,' or the Blue Nile, 'Muddy Nile,' or the Hwangho, 'Yellow (mud) River,' as a political boundary, unless there was a marked difference of racial type or nationality running approximately along the line of the river. In fact, I would suggest that the troubles along the Missouri were really due to the fact that the river was *nowhere* an Inter-State boundary, and therefore each State claimed the right to monopolise it in the particular section. If it had been an Inter-State boundary from the first, such a claim would have been obviously absurd. And it was the iniquity of the claim to monopoly that forced the United States, as similar conditions forced the Australian Commonwealth, to take over the control of the Inter-State rivers.

The principles behind the control are significant. Thus, the Murrumbidgee is entirely within New South Wales, as the Goulburn is entirely within Victoria; but the Murray is an Inter-State river—in a double sense, acting as the boundary between New South Wales and Victoria, and emptying through South Australia. New South Wales has entire use of the Murrumbidgee, and Victoria of the Goulburn, but the whole volume of the Murray up to normal low-water level is left to South Australia. In Europe navigation is usually far more important than irrigation. Why should not Europe exercise similar control over the navigable rivers of Europe?

For, geographically, great navigable rivers are essentially a continental feature, *i.e.* really a world feature, for all major continental features must be included in a survey of world features, even if they are minor world features; and the world can recognise no right of a political unit to regional monopoly of the commercial advantages of such a feature to the disadvantage of other political units—least of all, others in the same region. As with the irrigation when a river is obviously and entirely within an area where identity of culture and sentiment proclaims a natural or national unit, then that unit has a claim—even if it should prove impolitic to press it—to some monopoly of the facilities afforded by that river. But when the river runs through or between two or more such natural or national units, *i.e.* is really international, one of the units has no claim to any monopoly against the other or others.

It was reasonable that expanding Prussia should get to the mouth of the Elbe, and it was certain that Holstein had been both a fief of the Holy Roman

Empire and in the German Confederation of 1815, and that succession in Holstein could *not* go in the female line. It was equally certain that Schleswig had never been in either the Holy Roman Empire or the German Confederation, and that succession in Schleswig *could* go in the female line. The reasonable sequel in 1864 would have been for Prussia to purchase Holstein from Denmark, and share the facilities of the international river.

One would not expect such a view to be taken by a Prussian, but that was the actual principle laid down by France nearly one hundred years earlier. The famous Decree of November 16, 1792, asserted that 'No nation can, without injustice, claim the right to occupy exclusively a river-channel, and to prevent the riparian States from enjoying the same advantages. Such an attitude is a relic of feudal slavery, or at any rate an odious monopoly imposed by force.' This was not mere talk. It was followed, in 1793, by the complete freeing of the Scheldt and the Meuse to all riparians—France herself being a riparian in each case, for the Scheldt was naturally navigable up to Valenciennes. Somewhat similar rights were extended, in 1795, to all riparians on the Rhine—France herself, of course, being again a riparian; and in 1797 the freedom was extended, so far as France was concerned, to the ships of foreign nations, though Holland was able to make the privilege valueless.

The original Decree had not pressed the precise question of internationality. But, if the general principle holds—that a great navigable river cannot be monopolised by a single political unit against riparians, even if they are its subjects and of alien 'race'—still more must it hold when the river in question is fully international, flowing through or between two or more States. Of course, Rhine, Danube, and Vistula do both.

As a matter of fact, in Europe this principle has been generally accepted for the last century except by Holland. Prussia and Saxony agreed about the Elbe in 1815, and the agreement was extended to Austria, Hanover, and Denmark in 1821. Prussia, Hanover, and Bremen made a similar agreement about the Weser in 1823; and Spain and Portugal made similar agreements about the Tagus and the Douro in 1829 and 1835. Holland, however, has a very tarnished record, behind which there lurks some responsibility for all the blood shed along the middle course of the Rhine.

One has not an atom of sympathy with the arrogant German demand that 'small nations must not be allowed to interfere with the development of great nations, least of all with that of the greatest of nations,' and that Holland—simply on the ground of her small size—should be robbed of her three estuaries in the interest of Germany. But neither has one an atom of sympathy with the Dutch habit of taking advantage of that small size to behave in a mean and unreasonable way on the assumption that no Power except Germany would use force against such a little people. I would like to illustrate the position by an analysis of the problem on a canal, for one must include straits and canals with rivers. Their inclusion may involve some difficulty, but in the most serious case the difficulty is already largely solved. I refer to the Panama Canal during the second year of the war, when British shipping was exactly half as large again as U.S.A. shipping, amounting to very nearly 42 per cent. of the whole traffic The total result of the war, however, has been a loss of over 5,200,000 tons of British shipping, involving a reduction of 13.5 per cent. in our carrying-power at sea, while the U.S.A. tonnage has increased by nearly 6,730,000 tons, *i.e.* an increase of 382.1 per cent. in the U.S.A. sea-going tonnage (June, 1919).

The case which I propose to analyse is that of the Terneuzen Canal, and I wish to press it with all possible emphasis for three reasons: (1) it shows a typical case of quite natural—and, therefore, almost pardonable—human selfishness; (2) its supporters are guilty of an extraordinary blindness to their own mercantile *advantage*; (3) it repeats exactly what has occurred on the Meuse-Maas, only in such an artificial way as to make it very obvious.

Ghent is the second port in Belgium, and the first industrial town in Flanders. In the days before the separation of the two countries it was connected with Terneuzen, *i.e.* 'open-sea' navigation on the Scheldt, by a canal twenty miles long, of which rather more than half was in 'Belgian' and rather less than half in 'Dutch' territory, the actual sea-connexion being—unfortunately—in the Dutch territory.

At the time of the Franco-Prussian War the Belgians decided to enlarge the

canal, but had to *waste eight years* in obtaining the consent of the Dutch to the undertaking. Even then the consent was given only on the condition that the Belgians should pay for all work done by the Dutch, give an annual grant of some £13,000 for the upkeep of the new works, and grant Terneuzen preferential rates on Belgian railways! Some twenty-five years later it became necessary again to enlarge the canal; this was begun in 1895 on condition that Belgium again paid all the cost, that the Dutch had the right to close the locks 'whenever they deemed it useful to safeguard Dutch interests,' and that various other concessions were granted, *e.g.* about the Antwerp-Rosendaal railway; and the complete agreement was signed in 1902. The total cost was £1,600,000, a large proportion being spent *on the port of Terneuzen*; but the control is entirely in the hands of the Dutch, with the result that the Belgian part of the canal is both broader and deeper than the Dutch part, so that the larger Belgian boats even now cannot reach Terneuzen! That is to say, after all the cost, the concessions, the delay, etc., the trade of Ghent is still half-strangled, and may be cut off at any moment. Of course, the stupidity of the Dutch in thus crippling their own trade is unpardonable; but what about Belgium? Even then her boats have only reached the Scheldt—a river of little use to Holland, but vital to Belgium; and the Dutch pilot dues are 300 per cent. higher on the Scheldt than on the Rhine.

It has been typical, too, that, when the Dutch have granted any facilities, it has been done by a specific treaty, *i.e.* done as a matter of policy, not of justice. It was from this point of view that they agreed to the Lek and the Waal being recognised as the proper mouths of the Rhine. This emphasis on policy rather than on justice has not, however, been confined to Holland, though she alone still adheres to it. In Europe, in America, in Africa, and even in Asia, there have been, first, attempts to enforce a so-called political right of sovereignty against neighbours, *e.g.* on the Mississippi by Spain, on the St. Lawrence by us, on the Amazon by Brazil, on the Zambesi by Portugal, and then special conventions somewhat on the lines of a Treaty of Commerce. Such treaties grant commercial facilities, and power of navigation is such a facility; but if the navigation is on a great continental feature, such as an international river, surely the particular facility should be admitted *without* any special treaty.

This claim has been specifically put forward on several occasions. For instance, by the Treaty of Paris (1763) we had the privilege granted to us of 'navigation on the Mississippi to the sea,' and '*to* the sea' meant '*out into* the sea.' When the river passed under the control of the United States, the conditions were altered. Spain had granted no such facility to them, and she claimed the *political* right to block the estuary against them, while Jefferson claimed that they had a *natural* right to use the whole river, *i.e.* had such a 'right in equity, in reason, in humanity.' The same question arose on the St. Lawrence, where we claimed the political right to block the lower river against the United States in 1824. The case is specially important because Adams at once admitted the *political* right, *i.e.* the riparian 'sovereignty,' but claimed—as Jefferson had done—a *natural* right to use the river itself, a right which he based on necessity and on the support of the political Powers of Europe as formulated in many conventions and agreements and commercial treaties.

There had been so many of these that it had become possible to generalise as to a common principle—really the principle of justice; and so the Treaty of Paris in 1814 and the Congress of Vienna had adopted the principle, and had passed general rules in sympathy with it, rules which have been applied to many rivers and even to canals—*e.g.* in the old Kingdom of Poland. In the particular case of the St. Lawrence, the water right would not cover any right of portage; but, of course, the international boundary comes to this river from New York State below the last of the rapids.

In 1851 Brazil claimed the political right to block the mouth of the Amazon, but this was universally condemned as a gross misuse of the right of riparian sovereignty, for the mouth of the Amazon is even more truly than the Dollart an arm of the sea—so truly that it separates two distinct faunas; and, as the Plate was declared free in 1852, Brazil could not in decency exercise her dubious 'right.' It was not formally given up, however, till 1867; and it lies implicitly behind the recent so-called 'concessions' to Bolivia.

Portuguese law raised a similar difficulty in 1883 on the Zambesi. Of course, Portugal was our oldest ally, and our relations were very friendly; but, though she neither controlled nor traded with the interior, she claimed the political right to block the estuary against us, and we admitted the *political* right so far as to consent to her imposing duties—which, in theory, might have been prohibitive of all trade.

The Zambesi is specially interesting because it was concerned with one of the first of those land-corridors about which there has been so much discussion lately—the 'Caprivi finger.' Everyone except our lawyer politicians knew the real object, the certain meaning, and the probable result, of our conceding that strip to Germany—though most of us pictured German troops marching eastward along it to cut the 'Cape-to-Cairo' route in Rhodesia, rather than Rhodesians riding westward into Ovamboland. But theoretically the Germans made a demand for access to navigable water on an international river, and we recognised this as a reasonable demand, and granted it. Here, again, we stand historically in a position of great moral strength. Further, if we accept international land-corridors and international air-corridors, we must accept also international water-corridors, such as a navigable river or a narrow strait.

I do not want, however, to press an African example, partly because I do want to repudiate entirely the application of the Berlin Conference to any rivers outside Africa. For in 1884 Africa was essentially a virgin continent, and its inhabitants were completely ignored—in theory by all the deliberators, and in practice also by the nation which had engineered the Conference. For one of Germany's essential objects was to converge on the Congo, and squeeze out Belgian interests; and eventually, to do that, she did not hesitate to employ the most unscrupulous propagandists in this country on 'Congo atrocities.' It was, therefore, part of her scheme to press—what was accepted by the Conference—that the Congo should be open to all flags for all commercial purposes, and that *no riparian rights* should be recognised. It was equally to her interest that the International Committee of Administration agreed upon should never be set up, and it never has been; and, of course, in 1911 she used the trouble which she had provoked in Morocco, to acquire 100,000 square miles of the French Congo, so that she became a territorial Power in the West as well as in the East.

The whole question has two aspects—(1) the freedom of the actual navigation, and (2) the administration of the river. The former is largely a matter of equity, and so did not appeal to the Dutch or Portuguese lawyers; the latter is largely a matter of law, and has been much complicated by legal subtleties. But the two are closely connected, for the European rivers with which we are specially concerned, all have a lower course over the plain and an upper course involved in the folds and blocks of Central Europe. They are, therefore, important in the one case merely as carriers by water, and—all things considered, and in spite of superstitions to the contrary—are probably dearer as well as less flexible than the carriers by rail that cross them from west to east; thus the quantity of foodstuffs that reached Berlin—or New Orleans—by water in 1913 was quite insignificant. In the other case, however, they are of supreme importance, for their valleys focus the whole commercial movement, *e.g.* of Switzerland, both by rail and by water. This puts the people of the upper river-basin commercially at the mercy of the holders of the lower; at least a third of the Swiss imports before the war were from Germany, and a fifth of the exports went to Germany—much, in each case, done under what the Swiss felt as 'compulsion.'

In this particular case the people of the Rhine delta were also—politically—at the mercy of the Germans. For the natural outlets of the Rhine basin, such as Rotterdam and Antwerp, had taken on naturally the international character of all great ports, while the river-towns behind them, such as Cologne and Frankfort, were nurseries of intense national feeling, most carefully and criminally fostered by the Government with the declared object of presently imposing that 'nationality' upon the 'internationalised' port. One way of entirely undermining a position offering such opportunities to the unscrupulous is international control, with its impartial improvement of the waterway *on its own merits*. Thus, in 1913 nothing like 1 per cent. of the navigation on the Rhine was British, while over 65 per cent. was Dutch; but the deepening of the Rhine

up to Basel to admit sea-going vessels, *e.g.* from London or Newcastle, would instantly free the Swiss from their slavish dependence on *e.g.* Westphalian coal.

It is the political aspect, however, rather than the economic that I want to press for the moment. The economic aspect is useful only because it can be presented more easily in a statistical form, while the historic—though equally, if not more, illuminating—cannot be applied to recent events. We can see now that Peter the Great did not provide 'a gate by which (his) people could get out to the Baltic,' only one by which foreigners got into Russia; but we cannot have similar knowledge of the political value to Bohemia of the economically invaluable Elbe-Moldan. We can note, however, that it is essentially a way *out*, for the quantity of down-stream traffic (*e.g.* lignite, sugar, grain) is five times that of the up-stream traffic (*e.g.* iron, cotton, oils).

The agreements already mentioned, with regard to Elbe and Weser, Tagus and Douro, show that freedom of navigation has been granted as a reasonable courtesy for many years by nearly all civilised Powers, though even to this day Holland has persistently blocked progress by her stupid commercial policy and her unique position at the mouths of Rhine and Maas and Scheldt; and the essential principles are illustrated by the irrigation laws of Australia and the United States, where everyone now admits that the individual State cannot have any local standing, any riparian claims, as against the Commonwealth. All States, whatever their size or wealth or population, must be equal, though the natural advantages are with the upper riparians for irrigation as with the lower riparians for navigation.

The serious administrative difficulties are two—concerned respectively with the riparian sovereignty and with the different geographical conditions of different rivers or different parts of the same river; *e.g.* you can easily decrease the pace of the Rhine above Mannheim, but not without increasing the susceptibility to frost.

Historically, Riparian Sovereignty, in the case of Rhine and Danube, is only a relic of Feudal robbery. When they first became part of the civilised world under Rome, there was no such thing as riparian sovereignty. They were public property, which had to be kept in order and improved; and for this purpose the Romans exacted dues, which were spent wholly and solely on the upkeep of the waterway. The Franks continued the same custom on the Rhine; but the Feudal system brought in a horde of petty princelings—as impecunious as German princelings have normally been—who completely upset the old *régime*, converted public into private property, and exacted every kind of tax and toll. Unfortunately, because Rhine and Danube had been frontiers for Rome, they had been associated with a strictly military control, and the legacy of this favoured the Feudal princelings—as it also helped to poison the whole political development along both rivers, for they got only the worst side of Roman civilisation. Now we must go back to the primitive conditions. If an international river is a world feature, then its world relation is the first consideration. In that case, riparians must tolerate representatives of the whole world, or of such parts of the world as are most concerned with the particular river, on the executive for the administration of the river. In most cases, moreover, riparian sovereignty must be limited, even in the interests of the riparians themselves, for the presence of non-riparians on the executive may be, and has been on the Danube, of the greatest value in minimising friction amongst the riparians. In this respect France has played a most honourable part, generally supported by Britain, especially on the Danube, where, *e.g.*, Austria tried to exclude Bavaria from the deliberations about the river, and to dominate and intimidate the representatives of the lower riparians. Indeed, it was only the day before yesterday that we had the gratification of reading the German decision to 'exclude French and British representatives from the Danube Commission on the ground that they had hindered the ships of the more important nations from obtaining *priority* of treatment.' What greater compliment could have been paid to us?

The fact only emphasises the vital point referred to above, that different parts of the same river have different conditions and may need different treatment, *i.e.*, that even riparians have not all naturally equal use of the river, and that the strongest or the most favourably situated can grossly misuse their opportunities. The Dutch showed this on the Rhine in 1816, and

the Austrians on the Danube in 1856. Obviously, such differences are, in themselves, potential causes of serious trouble; riparians have not necessarily and naturally real equality even when the executive consists of only one representative from each riparian State. The greater opportunities of expansion, political and economic, on the lower river may favour the growth of a stronger Power; and the State with the largest share of the river or the best position on it has already advantage over the others. For instance, the Dutch on the Maas and the Russians on the Danube have indulged in 'voluntary negligence'; it was in this way that Russia blocked the mouth of the Danube, and it is in this way that Holland makes it impossible for the Belgians to *continue* their commercial navigation on the Meuse down through Holland to the sea. A low riparian may no more monopolise or ruin navigation on the lower course of a river than a high riparian may poison or exhaust its upper waters. The river is a unit, and its unity is essential to the fulfilling of its duties in the evolution of world commerce; and, therefore, it needs a unity of administration. This is best secured by a commission of riparians and non-riparians, and such conditions facilitate the use of a river as a political boundary.

Nearly all the important details involved in the internationalising of navigable rivers have been illustrated already in the history of Rhine and Danube, and in both cases France has been an admirable guide to Europe. On the Rhine, as I have mentioned, she abolished in 1795 most of the restrictions which had made the river practically useless even to riparians; and that she was not thinking only of her own interests was proved by her attempt—defeated by Holland—to extend the freedom of the river to all nations in 1797. Again in the Convention of Paris (1804) France enforced unity of administration—sharing this with Germany on the ground that the river was of special concern to herself and Germany, as she has shared the administration of the Niger with us in recent years on the same ground.

The Rhine thus received a simple, just, uniform administration, which is a model for us now. All tolls were abolished except two—one on the boat and the other on the cargo—which were to be only large enough to meet the upkeep of the waterway, and were to be used for no other purposes. These tolls could be paid in each political area with the coin of that area, but a fixed ratio was maintained between the various coinages.

Of course, in 1815 France was ousted from the bank of the river; and in the reorganisation elaborated by the Congress of Vienna Von Humboldt, the Prussian representative, adroitly introduced into the regulations for the Central Commission of Riparian Representatives words which were afterwards made to mean exactly the opposite of the freedom enforced by France, and exactly the opposite of what our British diplomats at the time thought and said that they meant! Not only so; but during the sixteen long years while France remained more or less submerged, Holland was allowed to make the whole scheme ridiculous by the claim that 'to the sea' did not mean 'out into the sea,' and that a tidal estuary was 'sea.' The Regulations of Mainz gave each riparian State full sovereignty over its own part of the river, and limited the right of pilotage to the subjects of riparian States; and in 1868 the Regulations of Mannheim further whittled down the old liberal principles of France—to the disadvantage of non-riparians, although they were admitted to rights of navigation. The Revised Rhine Navigation Treaty of that year was still in force in 1913, administered by the six riparian States—Holland, Prussia, Hesse, Baden, Bavaria, and Germany (as owning Alsace). Even since 1871 Prussia, as the strongest Power, has hampered the development of non-Prussian ports, using even the most childish tricks with pontoon bridges, choice of wharves, accessibility to rail, etc., against other German States.

Since 1871, too, the Rhine has illustrated another important point—namely, that the traffic on an inland waterway depends largely, perhaps vitally, on the extent to which railways are willing or forced to co-operate; and this has a present importance even from a purely international point of view. One of the results of the Franco-Prussian war was that Prussia bought up a number of private railways in the Rhine valley, and eventually used the profits of the transaction to make a secret fund for aggressive purposes. Now, if properly administered as an international waterway, the Rhine will be perfectly

free except for trifling dues on boat or cargo for the expenses of upkeep; and it will compete so favourably with the Prussian railways that their rates will have to be reduced to a minimum. This will cut hard at such differential treatment as has handicapped British trade in the last twenty years, and it will leave no surplus with which the unscrupulous can juggle.

Of course, the Rhine is essentially linked with the Meuse and the Scheldt—politically, economically, historically; and the Powers have long been too lenient or too timid with Holland, possibly because her purely *legal* position appeals to lawyer politicians. The Dutch base their claims to monopolise the estuary of the Scheldt on the Treaty of Munster (1648), but have greatly strengthened their legal position in recent years. The marriage of the Dutch queen to a German princelet was followed immediately by the intrigue that ended in Belgium definitely granting to Holland, in 1892, special rights on the Scheldt in time of war, and Germany strongly supported Holland in getting these rights extended between 1905 and 1908. But the Scheldt is merely an international river; it is navigable into France, and it was only by France waiving her claims in 1839, and proposing a dual control by Belgium and Holland—like that of the Rhine by France and Germany at the beginning of last century, and that of the Niger by France and ourselves now—that Holland ever obtained the power which she has abused. When Napoleon annexed Antwerp, he declared the Scheldt free; and the Rhine Regulations, when extended to the Scheldt, were interpreted as meaning 'free for all flags out into the sea.' Even so, the Dutch raised every possible difficulty, and navigation had no fair chance until the railway from Cologne to Antwerp brought in the only kind of influence which the Dutch seem to understand.

We have, therefore, full knowledge of all the essential conditions necessary to ensure the proper administration of international rivers, and shall have no kind of excuse if we are caught napping or misled by plausible and 'interested' tricksters. Amongst their last tricks is 'the great difficulty of policing such a river, where a German boat may be stopped by a French official.' That is not more terrible than a Rumanian boat being stopped by an Austrian official; and the experience on the Danube shows that there is really no difficulty at all—for the simple reason that offenders are always dealt with, naturally and reasonably, by officials of their own nation, just as the various European Powers have the right of jurisdiction over their own subjects in the Belgian Congo. In Article 25 the effete and Pharisaical Berlin Act of 1884-5 provided that its regulations for the Congo 'shall remain in force in time of war.' To-day we are less ambitious, and desire only to further safe, easy, honourable, intercourse, in time of peace, between nations that are unequal in size and population, wealth and power, situation and relation to navigation facilities. We have seen that one small nation may ill-treat another small nation from stupidity almost as easily and as grossly as a large nation may ill-treat a small nation from tyranny. Under the circumstances it seems necessary to remove from both the stupid and the tyrannical, the opportunities for misusing such facilities; and the obvious way of doing this is to make international rivers international in use and in government. Commerce is already a prime factor in the evolution of Human Brotherhood. Progress towards that ideal may be gauged as well by the price of a banana or a piece of chocolate as by the number of sermons preached on the subject; the sea is already free, made so mainly by British perseverance in clearing it of pirates; it only remains to make navigable rivers equally free, and the opposition comes mainly from those who have talked most loudly about 'the freedom of the seas.' But 'the freedom of the seas' does not mean that war is to be removed only from that element on which land power is weak, while the land power may still block access to the free sea by the natural avenue—the navigable river.

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SECTION F: BOURNEMOUTH, 1919.

ADDRESS

TO THE

SECTION OF ECONOMIC SCIENCE AND STATISTICS

BY

SIR HUGH BELL, BART., D.L., J.P.,

PRESIDENT OF THE SECTION.

AT last, after an interval of three years, the British Association resumes its meeting and takes up the business which the Council decided to suspend during the period of the war.

The meeting at Newcastle in 1916 found the world plunged in warfare of a most destructive character, and left us unable to determine either the extent of the destruction or the probable period of its continuance. Few would have then believed it possible that the following year would find the situation unchanged, and the outlook at least as black as in 1916. Much less would it have been believed that in the summer of 1918 we should be in even greater anxiety as to the final outcome, and that not till the early winter of that year should we be relieved of the nightmare of horrors under which we suffered in the five years which have elapsed since August 1914.

It is said that at a very early stage Lord Kitchener foretold a war of five years, and on his interlocutor protesting and expressing his belief that such a thing was impossible, reduced his estimate by one year, 'provided Russia held out so long.' The collapse of Tsardom coming when it did may be taken as fully justifying Lord Kitchener's estimate, for not till three months of the fifth year had run out were we greeted with the joyful news of the Armistice. Many months had to elapse before the Armistice was ended by a treaty of peace with our chief opponent. Even then we found ourselves still engaged in more or less active warlike operations in various parts of Europe, Asia, and Africa. Even to-day we are unable to review in any but a preliminary fashion the economic or other results of the war as a whole. We shall have to wait till long after our meeting at Bournemouth before a complete survey is possible.

Meanwhile, let us, in passing, take note of the fact that the cessation of hostilities did not carry with it the cessation of expenditure. The figures given each week in the *Economist* show the daily disbursements of the kingdom to have amounted to 6½ million pounds for the twenty-one weeks from November 16 to April 12. I append a table giving them for the twelve weeks prior to the date of the Armistice and for the twelve weeks following it, omitting the week in which it fell. It will be seen that whereas from August 24 to November 9 our expenditure amounted to 585½ million pounds, from November 23 to July 8 we expended 564 million pounds, a reduction of only 21½ million, or about a quarter of a million a day. This means that the debt with which the war burdened us continued to augment long after the cause of it had ceased to operate. The Chancellor of the Exchequer's statement in August that the expenditure even then exceeded four million pounds a day against pre-war expenditure of £541,000 shows that we are still vastly exceeding our income. Even if we take into account the interest on the war debt, which amounts to about one million pounds a day, it is clear that the various obligations undertaken by the Government during the war continue to impose on us a huge expenditure which is largely in excess of our revenue.

We have been led to believe that the huge expenditure of the last five years had gone, in part at least, into channels which would leave us with profitable and realisable investments. Some time will be required to demonstrate this, and we may still hope that the sale of the national factories will bring some relief to the burden of debt. It may be admitted that the process of 'cleaning up' is necessarily costly and slow, but it would be satisfactory to be able to record that the 'assets,' whether fixed or floating, had been of sufficient value to pay for their realisation, instead of being fed on the unsubstantial hope that at some future date vast sums will flow into the Exchequer as the 'surplus stores' remaining on hand in November 1918 are turned into cash, and the various factories sold or put to some useful purpose.

A cause of yet greater apprehension is to be found in the fact that new claims are made on the national purse and are accepted with the same apparent light-heartedness and disregard of consequences which mark so many previous acts of those responsible for our expenditure both during the war and before it.

We must recognise that we could not ask the multitudes of women who came forward to meet the call for munitions of war of various kinds, and for even more direct and active service at home and abroad, to abandon their activities and return to the conditions which satisfied them prior to the war. A like observation applies to the men who accepted the call of the nation and gave up their accustomed work to serve their country at the Front or at some employment at home quite different from that to which they had been used. Some compensation for these sudden changes was no doubt inevitable. The disorganisation of the whole industrial machine made it difficult, if not impossible, to turn these different classes adrift into a world in the chaotic condition into which the war had thrown it. But it does not follow that this compensation should have been given in a way actually to encourage unemployment. Tales, more or less authentic, pass from mouth to mouth indicative of the results of the ill-considered plans adopted to meet the difficulties which were no doubt most serious. The Irish farm labourer, offered a job at 30*s.*, who replied, 'Sure, I'm not likely to work for your honour for 1*s.* a week; I'm getting 29*s.* for doing nothing,' is one of these. The girl typist, paid the quite inadequate wage of 15*s.*, who gave up her work and at once received unemployment pay at 25*s.*, is another. Let us hope that the story of the navvy found smoking under a hedge, and, reproached for his idleness, who rejoined that 'he was engaged in working overtime at Cippenham,' is a fable, but it is of sort in which an unkind world may detect an element of truth. Whether true or not, these observations are of little importance in themselves except as indications of a general tendency to extravagant expenditure which must be checked before the course of our economic existence can return to normal lines. It should be the purpose of all patriotic citizens to accomplish that return at the first possible moment. To enable us to do this we must consider what has happened to the world economically since August 1914.

The first and perhaps most striking change to be noticed is that in these five years an immense quantity of wealth has been destroyed. I have had the sad advantage of paying a visit to the countries where the destruction can be seen. From the Belgian coast to Verdun, over a stretch of country from ten to as much as twenty miles or more in breadth and not less than 400 miles in length, I passed through a land where the effects of modern warfare were painfully visible. It is impossible to convey to those who have not seen it the extent and completeness of the destruction. For miles every sign of cultivation has disappeared. The trees with which in places the country was covered are represented by dead, unsightly stumps. We were told that these were useless even as firewood. They are so full of morsels of steel that it is impossible to cut them down or saw them up. They must stand till they rot. We passed through the pitiable remains of what the ruined walls and defaced gardens showed to have once been a village. But even more frequently we saw heaps of broken stones and bricks which, but for a board with a name on it at the side of the road, might have been taken for merely a more stoney and dishevelled piece of country. The epithet just used is more appropriate than one who has not been an eye-witness could suppose. The immense quantities of barbed wire which are being gradually

gathered up look like the fantastically ugly coarse tresses of some gigantic maenad.

Even more pitiable were the towns which bore still some semblance of life, just as a wounded creature inspires more compassion than one from which life has departed. Arras, for example, of whose beauty some traces remain in the picturesque great square and the adjoining Petite Place, with its lovely Town Hall, evokes a more poignant sorrow than Albert, or even Ypres, where the gaunt ruins of the Cloth Hall and Cathedral bear hideous testimony to the destruction worked by modern war. In all that part of the country the poor quality of the building materials have made the ruins most unsightly. As the traveller goes further east he comes into a region where a fine building-stone produces better houses and less unsightly ruins. But even there a shell makes a very hideous wound, and the remains, such as they are, have none of the dignity which Time bestows on human structures which have fallen into decay under his more kindly hand.

It forms no part of my subject to deal with the æsthetic side of the question, but I cannot refrain from expressing the horror with which I saw the ruins of Reims Cathedral. What has been said of the effect of shell-fire is infinitely true of the appearance of this wonderful monument of human art and human piety. Would it were possible to let it stand just as it is, taking means to guard it from the weather and from further damage, but not attempting to restore it to its pristine glory. The beautiful remains would be a perpetual monument to the shame of those who brought this irreparable injury to one of the most splendid examples of architectural art.

There must be many hundred thousand acres of cultivated land, with the apparatus required for its cultivation, which has been reduced to the condition I have endeavoured to picture. It is difficult to see how it can ever be brought again into use at any early date. The mere clearing away of the wire entanglements to which I have referred must be a costly operation. Great quantities of shell abandoned by the Germans in their hasty retreat still cumbered the ground they had occupied. These must be carefully removed—not a very simple operation, and one which must be carried out under skilled direction.

We saw numbers of ungainly tanks, the result of British ingenuity, left where their valiant occupants had been compelled to quit them. At one place we counted six of these in the space of a few acres. The removal of one of them was being effected by a valid tank, which was hauling a derelict to some place to be repaired or, more likely, to be broken up. I dwell on all this to try to bring home to you what must be done before what was once a smiling, prosperous countryside can be brought back to the state in which we saw the land lying outside the battle area on either hand.

Can anyone doubt the huge destruction of wealth which has occurred? But it is really worse than it appears, for the very process of destruction was even more costly than the damage which was done. Millions of tons of steel in the form of guns and their projectiles—millions of lives had gone to produce this untoward result. For fifty months all the energies of the most active and energetic people on the globe had been turned from beneficial enterprise to such work as that which produced the result I have sought to portray to you.

When all these things are considered it is not surprising to find our estimate of the cost of the war reaches a total the mind cannot grasp. When you begin to speak of pounds by thousands of millions the difference between twenty-five and forty is hardly noticeable. But be the sum larger or smaller, the all-important fact to be borne in mind is that the wealth which it represents has passed out of being.

So much confusion exists on this subject that it is worth while dwelling on it for a moment. Some contend that there has been a mere change of wealth from one ownership to another. Into whose possession, may we ask, has passed the wealth which used to exist in the towns and villages and cultivated land of the battle area? It is true that the steel which went to effect this destruction has been paid for, but from what source has that payment come? Let us think what might have happened but for the war. The steel might have made rails and been laid on a railway to bring the produce of

Central Africa to lands ready to pay for it and desiring to consume it for useful purposes. For all time there would have arisen in the process an income which would have gone to support in comfort those receiving it, and its surplus after this had been effected would have served to add yet more miles of railway and to bring yet more tons of useful produce. All this energy has been dissipated in the manner indicated, and all that remains is the obligation of the 'State' for all time to pay interest on a debt which has been created.

There is, as it seems to me, but one way to escape from the situation we have created. No measure of confiscation, however disguised, will remove the burden under which we lie. It may be decided to alter the incidence of the burden from one set of shoulders to another. Any proposal of the kind must have very careful and earnest consideration. If two men are journeying together, one carrying a heavy pack and the other none, it may well be that by dividing it they will reach the end of their journey sooner than by one carrying it all. But do not let us imagine that there is less to carry because it is borne by two instead of one.

It is sometimes said that all taxation is in the nature of confiscation. Is this really a valid contention? In the ordinary way taxes are levied for services rendered or to be rendered. It is indeed true that the tax is frequently not in proportion to these services. There is good reason to hold the opinion that at one time, if not now, the wage-earner paid by means of indirect imposts, which then were his only contribution to the revenue, an amount out of proportion to his income. It cannot be doubted that, what with tax and super tax and, in a certain measure, excess profits tax, the possessor of a large income pays much in excess of his percentage share towards the revenue. In each of these cases the excess payments smack of confiscation.

If a really sound and equitable scheme of taxation could be devised each taxable unit would contribute to the common fund raised for the purpose of the Government an amount which would be arrived at after due allowance was made for his services to the community and his ability to pay. A bachelor, with no claim on him but to support himself without State aid, who had done nothing to provide for a citizen to take his place in the fulness of time, might be called upon to pay more than a man under obligation to maintain a family and supply by his children the means of carrying on the torch of progress.

All kinds of refinements suggest themselves which show how difficult it is to give effect to the dictum that the amount of the tax should be regulated by the 'ability to pay.' It might, for example, be suggested that, since the thrifty man is better able to pay than the thriftless, some exemption should be granted to the latter. A graduated income tax presents the hope of a solution of the problem. Professor Edgeworth in the *Economic Journal* of June 1919 deals very elaborately with this question. He mentions the scheme proposed by Professor Castle in 1901, and says: "Distinction may be claimed for it on the following among other grounds: It is elementary, 'intelligible to the most untaught capacity,' a great merit in a principle of currency, according to Mill, and doubtless some merit in a principle of graduation." It may perhaps be questioned whether the pages which follow this quotation are so easily 'intelligible to the most untaught capacity' as Mill and the learned professor suppose. We may also doubt whether a careful man would fully appreciate the introduction into the equation of a modulus representing that particular ground for exemption which would cause him to pay relatively more tax than his less thrifty fellow.

One of the chief objections of graduation seems to be the danger of gradually increasing the steepness of the scale till the higher incomes would be taxed out of existence and the revenue they produced disappear. This would no doubt bring its own remedy. The State needs a certain annual revenue to provide the services demanded by the community. If the result of taking much the greater part of incomes over a certain amount ends by extinguishing these the State will cease to derive the revenue on which it counts. It must then either reduce the tax on them till a point is reached at which they will continue to exist, or it must increase the tax on all or some of the other incomes. Unless it means to rush headlong into bankruptcy, it must find the point of equilibrium at which its scheme of graduated taxation continues to produce the revenue

required, not in any one year, but in all future years. Such a scheme, could it be discovered, would meet entirely that very important desideratum of a tax, namely, that it should be based on ability to pay.

Two other points must be kept in view. A tax must be equitable in its incidence and reasonably continuous in its imposition. Given these three conditions the economic burden of the impost will quickly fall on the right shoulders. We may dismiss the argument which asks for a levy on capital and defends it against the accusation of being confiscatory on the ground that it is no more confiscatory than any other means of raising money by the State. No juggling with the balance sheets of the nations of the world will get rid of the fact that many thousands of millions of wealth slowly accumulated in the generations which lived before August 1914 have been dissipated.

If we confine ourselves to the more manageable figures which relate to our own activity we find that our public debt has risen from 710½ million pounds, at which it stood in 1914, to the colossal sum at which it stands to-day. The history of the debt in the hundred years preceding 1914 had been one of almost continuous reduction. From just over 900 million pounds in 1816 it fell to 628 million pounds in 1899. There were periods when the fall was arrested. In 1905 it had risen to 798 million pounds—a figure comparable to that of thirty-five years earlier. The Boer War was chiefly, but not entirely, responsible for this increase. In 1914 it stood considerably above the lowest point which it ever touched, but in the preceding eleven years every year but one showed a marked reduction.

In the last five years all this has been changed. From August, 1914, to March, 1915, 450 million pounds were added. The next year added more than 1,000 million pounds. By March, 1917, it stood at 3,906 million pounds, and now it has nearly doubled and is more than ten times what it was at the outbreak of the war.

It is true we have something to set against this vast sum. We have acted as the financial agents of our allies. The sums we have found for them amount to close on 2,000 million pounds. On the other hand, we have ourselves contracted debts abroad to the extent of well on to 1,500 million pounds. On balance, therefore, we have interest to receive on about 400 to 500 million pounds. But to enable the inhabitants of this country to find money for our Government we have sold fully as large an amount of our holdings in foreign securities. On balance it may be contended that we are little worse off. I fear in closer examination this view will not be found good.

Let us admit that our allies will find no difficulty in paying the 100 million pounds a year or thereabouts due for the interest on their debt to us. We must recognise that this will make a serious draft on their resources. Very different were the securities held by individuals in this country with which they parted to take up each successive issue of Government Bonds at the urgent insistence of successive Chancellors of the Exchequer. The securities sold were usually first-class industrial or public-utility issues. They might be the obligations of a Government in the wisdom and stability of which confidence could be placed; or the bonds of some great and progressive city, the money having been used to bring water to the inhabitants; or shares in some commercial undertaking to further the development of the country. In the great majority of cases we may assume that they had been invested so as to produce, directly or indirectly, a revenue to meet the interest. What have we got now? A charge on a heavily burdened country of which, it may be, many thousand acres have passed into the condition I attempted to describe a little while ago. I fear if an accountant from the planet to which Mr. Gladstone told us years ago we had banished political economy were to pay us a visit he would regard with no favourable eye the balance sheet which placed at their full value debts of the sort we are considering.

Put at the highest not many of our millions of pounds will find their own interest. All the balance must come out of the product of the other and real industries of the debtor country, and to this branch of the subject we must now turn.

At the present moment it is of more vital importance than ever that we should come to a clear and unprejudiced understanding on this subject. To

judge by appearances, the vaguest and most unsatisfactory opinions exist as to the capacity of the community to meet the various claims which are preferred for a share of the wealth from which alone these claims can be satisfied. Many people seem to think that no demand is too exorbitant. We are asked to provide houses by the hundred thousand undeterred by the consideration that they will cost two, three, or even four fold the amount at which they could have been built before the war. They are, moreover, to afford accommodation of a much better character than was thought sufficient a very short time ago. Houses built as recently as twenty years ago are no longer good enough for the social reformers of to-day. It is forgotten that something like 80,000 houses are needed each year to accommodate the growth of the population. There are to-day something over eight million inhabited houses in Great Britain. Not more than half of these are more than fifty years old. During the war housebuilding had almost ceased, but before 1914 the building of houses had been checked by two causes. The various Acts of Parliament dealing with matters affecting the building of houses had so enhanced their cost that there was the greatest uncertainty whether houses could be built to return a reasonable interest on their cost.

But the second cause was of as great, or possibly even greater, significance. The trade unions connected with the building trades had gradually succeeded in imposing conditions which had added enormously to the cost of building. It would not be difficult to show why this had been possible, but it would take me too far to follow this line of thought. The fact will not be denied by anyone conversant with the circumstances. The result of all this is a serious shortage of houses, and this it is proposed to make up by grants from the public purse. If this were the only demand of the kind we might face it with more equanimity than is in fact the case. But when we look elsewhere we see other claims comparable in their effects on the public purse but differing in kind.

The railway enterprise in this country may serve as typical of what is meant. Prior to the war the railways were carrying on their duties in a manner which enabled the country to get through its business in a profitable and, on the whole, fairly satisfactory way. They earned sufficient revenue to pay a fair return to the shareholders. It is true the prospect was not reassuring. The railway management was meeting the usual contradictory claims preferred against almost every industry. It was asserted that they were rendering services which were not nearly as great as were demanded by their customers, and they were charging for them rates which were regarded as quite out of proportion to the value of the services. On the other hand, they were paying wages which the recipients thought entirely inadequate for much longer hours of service than their workmen were disposed to give. Negotiations between the parties had obtained certain concessions as to hours of work, and also as to rates of pay; but these were not accepted as sufficient, and Parliament was called upon to intervene, with the result that statutory hours were imposed.

The very essential difference between hours of work or rates of pay resulting from convention between the parties interested and the same imposed by statute is often overlooked. The convention can be varied to meet the varying circumstances. The statute provides a hard and fast rule, from which it is impossible to depart without incurring penalties. An example of this may be found in the Cleveland Ironstone Mines, which, by a series of strange accidents, come under the Coal Mine Regulation Acts, and are thus subject to all the conditions imposed by statute on these. Employers and workmen are agreed in desiring to modify the provisions of the Acts as to hours of work on Saturdays. Their joint application to the proper Department for permission to do this has been refused for reasons which that Department (quite properly) regards as unanswerable. The officials decline to exercise a dispensing power and require that the provisions of the Act be rigidly followed.

When the railway companies pointed out the serious effect which these statutory obligations imposed on them had on their revenue-earning capacity and sought power to increase the rates their customers were up in arms. The very men who, in Parliament and elsewhere, were applauding the decision to give relief to the railway servants, resolutely refused to pay the extra cost thus incurred. With difficulty was Parliament induced to give the com-

panies leave to add to their charges something towards meeting this cost. The companies found still greater difficulty in obtaining a settlement with their customers as to the amount which should be so added. The question was still awaiting a final settlement at the outbreak of war.

But the case of the railways seems irrefragable. They point out that their earnings are barely sufficient to meet the claims on them and leave a suitable return to their shareholders. And when answer is made that these critics and customers are indifferent as to this, they point out that, unless they can do it, they will be unable to meet the demands of the districts which they serve. No railway in a prosperous and growing district can continue to render the services required unless it is able to raise capital to be expended on the provision of those additional facilities for which the expansion of the district calls. But to attract capital the railway must be able to show a revenue of which the surplus, after meeting all expenses, will serve to pay adequate interest. Even before the war, the never-ceasing demands of the workmen, and the ever-increasing obligations placed on the companies by Parliament as to the facilities to be given, were rendering it more and more difficult to find the necessary capital. It cannot be said that the return to the shareholders of all classes was inordinate. The 1,300 million pounds of railway stock earned a surplus of 50 million pounds in 1913—not quite 4 per cent. It is evident, therefore, that one or other of the following things must happen. Either the railway development must cease, and with it, to a large extent, the development of the country, or the revenue must be increased per unit of traffic, or the expenses must be diminished either by reduction of the actual charges or by improvements in the methods of operating.

We may dismiss the first of these possibilities, for we must decline to believe that the country will cease to develop. It would be with great reluctance that we should accept an increase of the charge per unit of traffic. We would rather hope that by adopting better operating methods we should reduce costs and so reduce charges. It is to this side of the question that we must address ourselves. In doing so we may pass from the special case of railways to the general case of the national industries.

There has been a persistent demand by labour throughout the country for better pay, and an equally persistent demand for more leisure. To these demands no objection can be taken. On the contrary, rightly understood, they must meet with approval by all who desire to see the country, as a whole, happy and prosperous. But we must consider how they can be satisfied. This is a question to which recently a great deal of attention has been given. In its satisfactory solution lies all our hope for the future.

To begin with, the only source from which satisfaction can be is the sum-total of the product of the industry of the country, and indeed of the world, in the period under consideration. It must be noted that in many cases the product may not be realised within that period, as, for example, when a manufacturer holds large stocks of goods which he has not yet marketed, but on which much the greater part of the cost has been paid. It must also be noted that a very considerable part of the industry of the country does not add to the total product which is the subject of division, but is in fact a charge on that product. The whole burden is borne by those engaged in providing commodities or services necessary for the members. We touch at this point a very difficult problem, the proper solution of which may possibly show us how all our economic troubles may be ended. I can do no more than state it as briefly as may be.

There can be no question that a very great part of human activities is spent, and the resulting product used, in providing things which cannot be called necessaries of existence. The simplest food, clothing, and shelter may be said to cover all that comes under this head. But life that gives us nothing but the indispensable minimum of these essentials would be so dull and monotonous as to be hardly worth the exertion needed to procure them. We must have more than these if we are to get enjoyment as well as mere life. How much more can we claim—perhaps we might say, extort—from our environment? And how shall this extra tribute be shared among us?

If we made a complete analysis of the result of the product of industry we should be astonished to find how large is the amount which remains after the

essential demands have been satisfied. Take a survey of some town you know and ask yourself what the multitude of public-houses and picture-palaces indicate but a spending of money on non-essentials. Or look nearer home, and consider whether the things you could quite easily spare do not bulk very large. If we sought to classify our expenditure we might come to some such division as this:

On essential needs.
On things making for the irreproachable amenities of life.
On luxuries which add to and aid our reasonable enjoyment.
On those which subserve mere pleasures.
On extravagant expenditure for which no justification can be offered.

It is difficult to draw any clear line between the heads of this very rough division. Each class passes imperceptibly into the next. Fortunately for our present purpose we do not require to do this. It is enough that we should admit that not all activities are well directed, and that we consume a great many things we could do without. No class is exempt from this blame, if blame it be. Each is disposed to look askance at what is called the extravagance of some other. When people talk of waste, they often mean expenditure on things for which they themselves do not care. But the question is how can we check this extravagance and provide more fully for the more essential needs of the whole people?

If rich men did not drive motor cars or drink costly wines, would the people who produce these luxuries be better off? Or if, instead of making these things, they made articles needed for the mass of the people, could these buy the result if they had no more means than they now possess. Do we not come back at the end to the proposition that men can only have more if they have more to offer in exchange? The great mass of mankind labours to gain 'daily bread.' If more is produced, more of these necessities will be satisfied.

It may be contended that men have obtained more or less completely what they wanted most urgently. They wanted shorter hours. In many trades they have got them, and might have had them in more had they gone about it in the right way They were not sufficiently desirous of having better houses, and they failed to procure what their wellwishers desired for them. It remains to be seen whether the movement in this direction, to which reference has already been made, will produce the results which we all desire to see—though some of us would like to see them obtained under more satisfactory economic conditions than are at present proposed.

A relatively small part of the population do unquestionably get a very large share of the total income produced by the whole community. Can we do anything by which this share may be reduced without bringing about greater evils than those we seek to overcome? The history of the sumptuary laws do not encourage much hope that attempts to prevent expenditure in particular directions will have much success. My own studies had brought me, many years ago, to the conclusion that in every industry examined there is no way of giving to those engaged shares greatly differing from what has been afforded in the past. The margins on which manufacture in general is conducted are too small to make it possible to give the larger contributors to the ultimate result any considerable addition to what they have been accustomed to receive. This impression was confirmed by the elaborate general survey of the industry of the kingdom carried out by the Census of Production of 1907.

No doubt labour (which is much the most important item of cost) has obtained a gradually increasing payment, though not necessarily any larger proportionate share. A steady improvement in the methods in which the labour of men is applied has resulted in enabling a larger product to be obtained. Each new implement, each fresh application of energy of various kinds, as, for example, steam and electricity, has meant that the individual man produced more in his day's work, and he got, in fact, a large return for what he did. But at the same time, the capital engaged was increased, and consequently the proportion of the product to be allotted to rewarding capital also increased. It is neither possible nor desirable to attempt to alter this state of things.

The whole question has been treated in a very masterly way by Professor Bowley in a book published some months ago entitled 'The Division of the

Product of Industry,' a title I had myself adopted for a lecture I gave at the National Economy Exhibition in July 1916. Mr. Herbert G. Williams's pamphlet entitled 'The Nation's Income' also deals with the same subject with much care and skill. In it he makes a critical examination of Sir Leo Chiozza Money's book entitled 'Riches and Poverty.'

The conclusion reached in these publications is practically the same. It may be stated in the cautious words with which Mr. Bowley ends his book :—

"This analysis has failed in part of its purpose, if it has not shown that the problem of securing the wages, which people rather optimistically believe to be immediately and permanently possible, is to a great extent independent of the question of national and individual ownership unless it is seriously believed that production would increase greatly if the State were sole employer. The wealth of the country, however divided, was insufficient before the war for a general high standard; there is nothing as yet to show that it will be greater in the future. Hence the most important task—more important immediately than the improvement of the division of the product—incumbent on employers and workmen alike, is to increase the national product, and that without sacrificing leisure and the amenities of life."

These statesmanlike words need to be borne in mind by all who are engaged in dealing with the difficult problems of to-day.

I shall have failed in my object if I have left my hearers under the impression that I am wedded to or pleading for any particular division of the wealth of the country. We hear much talk about abstractions called "capital" and "labour." The terms are convenient enough if we do not let ourselves be deluded with the idea that they mean more than the sum of those who own the capital or supply the labour. Labour itself is a somewhat ambiguous term. Till comparatively recently the members of the 'labouring classes' so called thought it was synonymous with the man who laboured with his hands, and 'the horny-handed son of toil' was contrasted with 'the pampered minion of luxury.' The Labour Party itself has been fain to enlarge its definition so as to include all those who 'labour by hand or brain.' If we could be brought to see that there is no hard-and-fast division of men and women into the one or other of these classes, but that nearly all of us belong to both, a good deal of our present trouble would disappear. Not one of us, if independent of capital, the most poverty-stricken member of the community relies as implicitly on it as the richest among us. To talk of the 'abolition of capital' is to use a form of words which is absolutely meaningless. What most people who use them really mean is one or other of two things, sometimes both at the same time—either that the capital is in the wrong hands and that it should not be held in the way or to the amount which is at present the case, or that the division of the joint product of capital and industry is defective, and should be altered.

It will be seen that these are two quite different questions, and call for consideration on quite different lines. If great aggregations of wealth are deemed undesirable the community may take means to limit the amount held by any one man. But where the line should be drawn is a very difficult problem. It would be easy to show that human progress has depended on the thrift of our ancestors, and to prove that, in like manner, our future progress depends on a continuance of this policy of not spending on the enjoyment of the hour all the product of our industry. Implicitly this assumption is made by every one who criticises the condition of our various industries in this country and compares them unfavourably with those of other lands. They are, in fact, saying that our railways or mines or steel works have been starved. Yet, with almost the same breath, they complain that the men engaged have been insufficiently remunerated for their labour. I see great difficulty in saying no man's fortune shall exceed some given sum, and even in saying no man shall bequeath to his survivors more than some very moderate amount. In either case I should fear endangering that building up of capital which, however it may be divided, is essential to our national progress.

When we come to the division of the joint product of industry and capital other considerations become apparent. The question at once arises whether any other division would have been possible in the past, or could be accomplished in the future, without great changes in the way in which the product arises.

Reference has already been made to my own examination of this matter, which leaves me in no doubt that any considerable increase of the part of labour would have left the share of capital so small as to have stifled enterprise.

This does not mean that large fortunes may not have been made by those whose skill and industry and enterprise enabled them to seize the advantages presented to them. If an illustration may be drawn from the history of my own firm, I may say that over and over again have we embarked on undertakings which we had in the end to abandon as unprofitable. Those who were, in fact, our co-adventurers, the men whom we employed, ran no risk. They were paid the sums to which they were entitled as the result of bargaining in an open market. The wages paid were those ruling in the district. Such machinery or other supplies as were needed were bought as cheaply as was possible. We took all the risk, and bore all the loss which often resulted. We had no qualms about taking the profit when any ensued. The capital which by incessant industry and application has been thus accumulated has served to provide employment for the sons and grandsons and remoter descendants of those who first worked for my father and his brothers seventy-five years ago this very year.

Those who cry out against capital overlook the fact that in modern industries no man can be set to work except by means of a capital sum first found for the purpose. In the industries I know best something over £200 is needed to put a man to work. The population of this country increases at the rate of about 1 per cent. per annum. This means that for every 1,000 men to whom employment is being given about ten youths are ready to be set to work each year, and something over £2,000 must be found year by year to give them employment. It is not an unreasonable boast for a captain of industry to say that in this respect he has performed his duty to the community.

One further point must be made. Men see some great enterprise (and the railways will serve very well as an example), and look upon it as a capitalist organisation. But when the circumstances are examined it is found that it consists of a multitude of small holdings, and comparatively few of large amount. In the North-Eastern Railway something like 60,000 shareholders hold the 83 million pounds of capital of various denominations—say, on the average, some £1,600 each. Consider the widespread distress which would be caused if the income from the sum were to cease.

I have made a similar calculation for a large colliery undertaking in which I am interested, with the following result. The capital in shares and debentures is about £1,300,000. There are just over 1,800 shareholders. We employ 5,500 men. Each shareholder therefore provides employment for about three men and holds on the average £725. Before long we shall require further capital. We see our way to enlarge our operations and so to provide employment near to their homes for the 50 to 60 youths who, each year, grow to manhood and need productive employment if they are not to become burdens on the community. We hope our 1,800 shareholders will have laid by enough to provide the £12,000 a year which is necessary for this purpose. We are assuming they or someone will provide it, for we are using our resources (reserves and depreciation funds) in this way, and shortly it will be incumbent on us to fund this obligation and add it to our capital.

Let us be very cautious how we interfere lest we produce evils infinitely greater than those which it is sought to remove. What, for example, will those 50 to 60 young men say, if we reply to their applications to be given work with us, that all our resources have been used in paying additional wages, and we have accordingly been obliged to let our plant deteriorate instead of adding to it and that, far from offering additional employment, we fear we may have to dismiss men to whom we at present give work?

We are thus brought to the last subject which I desire to consider with you—the widespread tendency towards what is somewhat vaguely called Nationalisation. It may be questioned whether any large number of people have very clear ideas what is meant by the term.

Let us assume for the present purpose that it signifies that the State shall become the owner of any enterprise which is nationalised—as it owns the business—the Post Office, the Telegraphs and the Telephones. Let us ask what advantage will be gained by the assumption of ownership. A centralised

management even of so simple a business as that of collecting and distributing letters and parcels has not been an unqualified success. Where the business is more complicated, as in the other examples, the success has been even less conspicuous. What reason have we to hope then in such intricate matters as the Railways or the Mines better results will follow?

The incentive of individual gain will have disappeared and with it the readiness to accept such risks as those to which reference has already been made. We may easily find that the developments needed to find employment for our young people is not forthcoming, for without such risks being taken no growth of employment will take place. Unless I am much mistaken a great temptation will be put before politicians to make concessions to the huge army of voters who will be in the direct employment of the Government.

The experience of these five years has failed to teach the lesson that you cannot touch one branch of labour without affecting all others. An advance of wages given to one section will inevitably be demanded by all others. The result will be prejudicial to the whole community. As regards each individual trade it may be of little moment what we call the wages, the wage earner has in the past obtained a certain (very large) percentage of the whole value of the product; whether it is called one hundred or two hundred is of little moment unless indeed he can succeed in obtaining for himself higher rates of wage than those prevailing in other industries. But as regards international trade the position may be very different, and we may find ourselves shut out of foreign markets because our wages are made artificially high, just as we should be excluded if, for example, the shipowners could compel us to pay inordinate freights on some indispensable raw material like cotton.

A cure will speedily come, but it may come after great suffering has been inflicted on the whole community. Parliament can easily impose on the employer, whether a private individual or the State, the payment of a certain wage if a man is employed, but one thing it cannot do and that is compel the employment of the man at a wage which the price of the article he produces will not suffice to pay. The man will remain unemployed. That is the drastic remedy which economic law imposes. We may escape it by making up from some other source the deficiency if we insist on having the article and refuse to pay the cost. But this remedy is only applicable to some small part of our total product. When we come to such industries as those now talked of it is impossible. We must make the industry self-contained.

The hope that by transferring its ownership to the State from the individual will enable us to pay more is foredoomed to disappointment. There is indeed one—and only one—way in which higher wages can be obtained. That is by a greater product per unit of capital and per unit of wage. If an article now produced at a combined capital and labour cost of, say, 100 can by improved methods be produced at, say, 80 and still sold for 100, and if capital is still satisfied with its former share, then the whole of the extra 20 will come to labour. Long experience teaches me that it is in this way that wages have advanced in the past and that in this way alone can they be further increased in the future.

But it may be said that those most concerned are not striving alone, or even chiefly, for higher wages, but desire to participate in the management and to bear their part in deciding the questions of policy which up to now have been in the hands of the employers. To this no fundamental objection can be raised. The more completely the men engaged in any enterprise understand it the better it will probably be for the whole. But large questions of policy require knowledge and appreciation of circumstances which can with difficulty be acquired by persons whose life is necessarily passed in quite other surroundings. That the fullest information should be given to the persons in question cannot be denied. The claim to deal with matters of management lying quite beyond their competence cannot be conceded. The final impulse comes from one mind which cannot divest itself of its responsibility nor exercise it under such conditions as those suggested would impose.

In the brief compass of an hour I have sought to describe the difficult situation in which we are placed and to enumerate some of the intricate economic and social problems which call for solution. It is impossible to view the future

without apprehension. A universal unrest pervades the world. This had indeed already become apparent before 1914. The war has exacerbated the symptoms which were already sufficiently menacing. Remedies by legislation had been applied here and elsewhere without success. In the nineteenth century the political emancipation of the inhabitants of this country was gradually effected. By the end of it freedom had been practically won. The great changes which occurred in the political condition of the country as it was before 1832 and as it became by the end of the century had been brought about with relatively little trouble. It is not surprising that this should have led to the conclusion that economic changes could be effected with equal ease. Perhaps the confusion which we continually observe between a 'law' imposed by the will of a legislature and a 'law of nature,' so called, is responsible for this confusion. Parliament, we are told, can do anything except 'make it rain or hold up.' It may perhaps even effect this by enacting that under certain circumstances it shall be 'deemed' to rain or hold up, as the case may be. But the most ardent believer in the power of legislation to bring about important changes will not be prepared to deny that, whatever the legislators may say, he who goes out in the rain will get wet.

Having gained political freedom comparatively easily people seem to have thought economic freedom would be got with equal facility. We have had numerous instances of this on which it is unnecessary to dwell. Concessions have been made by which, apparently, life was made much easier for certain people. But the fund out of which these concessions were to come has not been increased. Many of them, though not so intended, had the effect of positively lessening that total. In a perfect world it ought not to have had this effect, but, human nature being as it is, it was easy to foresee the result. It could have been foretold that a minimum wage established by law would sooner or later reduce the output of the man paid by piece. It had that effect on the coal miners at a very early date after its enactment.

The demand for higher wages without corresponding increased output was causing anxiety before the outbreak of war. The inordinate expenditure which the war brought with it seemed to justify the contention of the workmen that the claims they had put forward would easily have been met in the past and must be conceded when things became normal again. It was forgotten that all thought of economic production had ceased. We were living, not on the earnings of the year, but on credit raised on our expectations of the future. In the past this course was also pursued, but (as has already been pointed out) in very different circumstances, for the capital thus created was calculated to yield an adequate return to the persons interested.

It is to be feared that the limitations imposed are not appreciated by those who will be most affected. The Legislature reduces hours from eight to seven in the coal mines. The miner claims that his earnings shall not suffer. Circumstances make it difficult for him to get as much coal in seven hours as in eight even if he were willing. It is hard to see how we can escape the conclusion that the coal will cost more. The coal owner alleges that he is unable to pay the higher cost except by obtaining a higher price.

None of the remedies proposed touches the difficulty. We must obtain a larger product if we are to have more to divide. Restrictions in output, whether produced by the act of the Legislature, the will of the worker or (let us add) the hindrance of a tariff, will fail to effect this. None of the short cuts now proposed will lead us to our goal. Can we convince those most deeply interested of the truth of this? The task is not an easy one, for promises without end are made to accomplish what is desired without pursuing the patient and laborious course which alone can lead to a happy solution. For my part I rely on the common sense of my fellow countrymen. The speedy abolition of all artificial prices by which we shall get to know the real cost of what we buy will be a great help. We may hope that on this will follow an earnest desire on the part of all to do their best for the commonweal—convinced that on this intelligent altruism we are best serving our own ends. A better division of industry would ensue. The net result would be a happy and contended nation, in which the efforts of each would be more guided by the common welfare than by the selfish desire for the advantage of the individual.

Perhaps employers and employed alike will come to see how greatly a strike or lock-out militates against the true interests of both. Perhaps the men will learn that the party in the State to which they belong suffers much more than any other by these occurrences. Is it too sanguine to hope that, as Professor Cannan says, we may drop 'the notion that trade is a kind of war, whereas it ought to be regarded as co-operation between friends, none the less friendly because they bargain and even haggle.'*

None of these things can be accomplished by Acts of Parliament. Statutory prices and statutory hours offer no solution—rather increase the evil than lessen it. There is no Royal Road by which we can travel to a solution. We must by patience and mutual forbearance seek to alter the present hostile attitude. We may frankly accept Professor Cannan's opinion 'that the economic organisation of the nineteenth and early twentieth centuries will not endure for ever, but will be gradually replaced by something else more suitable for its own day and generation.'†

Let all parties in the State bend themselves to this change, in which again, to quote Professor Cannan: 'Free associations of free men able to go out and come in as each pleased, would voluntarily give service for service, irrespective of domicile and nationality.' This is a change which we may agree with him in thinking more 'desirable than any restoration of the feudal system basing economic organisation on the territory of the lord, even if the personal lord of the Middle Ages is replaced by a Parliament elected by universal suffrage and proportional representation.' ‡

PUBLIC EXPENDITURE.

Twelve Weeks before the Armistice.

Period Ended—	Supply Services	Interest on War Debt	Total Expenditure
	£	£	£
August 24 . .	40,375,000	708,661	41,473,661
,, 31 . .	51,939,848	3,059,437	55,169,201
September 7 . .	44,130,000	813,337	45,098,369
,, 14 . .	50,317,042	845,986	51,526,856
,, 21 . .	40,670,000	828,506	42,119,686
,, 30 . .	42,402,700	2,974,400	46,780,500
October 5 . .	38,190,000	20,804,188	61,410,931
,, 12 . .	36,105,554	2,904,670	39,729,851
,, 19 . .	49,319,000	2,136,672	51,755,672
,, 26 . .	44,355,000	887,398	45,542,398
November 2 . .	47,575,326	1,218,924	49,104,416
,, 9 . .	54,569,871	926,003	55,806,254
	539,949,341	58,108,182	585,517,795

Coal Nationalisation, p. 25.

Ibid. † Ibid.

Twelve Weeks After the Armistice.

Period Ended—	Supply Services	Interest on War Debt	Total Expenditure
	£	£	£
November 23 . .	30,250,000	16,303,458	46,553,548
,, 30 . .	39,413,243	819,929	40,428,336
December 7 . .	42,100,000	49,114,929	91,920,829
,, 14 . .	42,459,404	6,322,606	49,224,649
,, 21 . .	51,571,000	1,340,988	53,003,201
,, 31 . .	60,256,704	2,705,130	64,517,390
January 4 . .	22,600,000	834,265	24,874,084
,, 11 . .	26,141,098	1,098,690	28,294,788
,, 18 . .	38,000,000	689,592	38,960,389
,, 25 . .	31,847,000	573,109	32,420,109
February 1 . .	49,914,702	788,404	51,153,272
,, 8 . .	41,625,296	1,097,589	42,733,265
	...	..	564,083,770

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ADDRESS

TO THE

ENGINEERING SECTION

BY

PROFESSOR J. E. PETAVEL, D.Sc., F.R.S.,

PRESIDENT OF THE SECTION.

During the last five years every resource of the Empire, moral, intellectual, and material, has been concentrated on one great task, now successfully achieved; and the present period marks the end of a gigantic military struggle and the beginning of a new social era.

I.—*Engineering and Science during the War.*

To summarise adequately the part played by engineering in the war would constitute a task far beyond the power of the writer or the scope of the present address. Now, as in the past, the fate of nations in war or peace is primarily determined by moral, intellectual, and physical attributes; but, under modern conditions, these forces can find efficient application, only through the agency of science and engineering.

A large army depends for its subsistence and equipment on the combined effort of every branch of human activity; and every productive industry, when organised on a large scale, is in turn dependent upon the engineer.

Before the end of the war this country had become transformed into one vast factory, every department of which required the services of trained engineers. Every member of this section has contributed his own share to the task, and our programme includes papers giving detailed accounts of several branches of the work.

It is fitting, therefore, that I should restrict myself to a mere outline of some of the more outstanding facts:—

The urgent necessity for an output of munitions vastly in excess of any previous production made centralisation and standardisation essential, and involved a complete revolution in workshop practice. The Ministry of Munitions was responsible for the formation of the required organisations, and guided the transformation of industrial conditions, and, when the dilution of skilled labour become inevitable, the technical engineer designed the machinery and devised the methods which made efficient work possible.

Credit is due to the Unions for the concessions made; greater credit to the women for their enthusiastic response to the call and the steady output they maintained.

Munitions.—The Ministry of Munitions was created in May 1915, its early efforts being concentrated on the production of guns and shells. A year later the Ministry was in a position to meet the ever-increasing demands of the Army, and by 1918 a large reserve of munitions had been established, the expenditure being limited only by difficulties of transport at the Front. The maximum expenditure of ammunition was reached one day in October of that year, when 900,000 shells, weighing 40,000 tons, were fired. The total number of guns

manufactured during the war was 20,000, and over 200,000 machine guns had been delivered by November 1918.

The Ministry of Munitions took charge also of the production of aircraft, which were ultimately turned out at the rate of 4,000 per month; later the provision of motor transport was in addition placed under its control. Finally, our production of 'poison gas,' for which this Ministry was responsible, rose during the last few months of the war to several thousand tons a month, sufficient to make the Germans rue the day on which they had introduced this weapon into warfare.

Among the inventions which have had an influence on military operations I will mention only three as typical of three distinct classes:

Tanks were first used in 1916, and the results produced were greatly enhanced by the surprise created, and consequent moral effect, but the idea of an armoured chariot is as old as organised warfare. The problem of constructing a vehicle which could travel across the trackless and shell-pitted district which extended between the two armies remained to be solved. In the light of the experience gained with various types of tractors it was, however, clearly not insoluble, and credit is due to the man who had the courage to hazard a novel and important experiment. The resulting tank was the product of careful design and experiment, and the outcome of the co-operation of several engineers with special knowledge. Sound-ranging introduced the complex methods and delicate instruments of physical research into the trenches, and, against all precedents, proved them to be reliable and practical under the most adverse conditions. The Stokes gun, on the other hand, superseded all other trench mortars by simplicity of design of manufacture and convenience in handling; 20,000 of these guns were used during the war.

Transport.—On August 4, 1914, the Government assumed control of the railway systems in this country, but the working and management was left in the hands of the railway officials, and to them is due the smooth working of the lines during a long period of exceptional difficulty. British engineers, civil or military, have been responsible for the transport through France, and during the last two years of the war large numbers of engines were sent across the Channel and miles of track was taken up in England and relaid in France. Road transport was organised on an unprecedented scale, and 100,000 new vehicles were delivered. A network of narrow-gauge railways was carried right up to the trenches, and numerous new roads, railway lines, and bridges constructed. Railway construction formed an important factor in connection with the advances in Mesopotamia and Palestine; in the latter case the entire water supply had for a long period to be drawn from the Egyptian base through a specially laid pipe-line.

In France and elsewhere the armies were primarily dependent upon sea transport for their food and equipment. This service, organised by the Navy, culminated in the unique effort which brought American troops at the rate of 300,000 per month, and thus overbore the balance which for four years had been oscillating between defeat and victory.

Among the notable new departures the cross Channel train ferry and the portable steel bridges, principally of the Inglis type, should be specially mentioned.

Navy.—At the outbreak of war the Navy was ill-prepared with regard to anti-submarine defence and mining. The influence of the submarine on naval warfare had been under-estimated, and mines were regarded as a somewhat discreditable means of destruction; but during 1915 the depth-charge and the Paravane were developed by the naval experimental department at Portsmouth, and later thousands of these were brought into use. In principle the depth charge consists of a canister containing a large charge of explosive and a pistol actuated by an hydrostatic valve. The merit of the invention resides in the simplicity, safety, and reliability of the mechanism. In designing the Paravane the body was borrowed from a torpedo, and wings, rudder, and elevator from an aeroplane. The secret of the device lies in the stabilising mechanism, which enables it to keep its position when the ship is running at high speeds. The Paravane enabled most ships to pass unscathed through a mine-field, and in a slightly modified form it served to seek out and destroy submarines under the water.

Sound location proved to be one of the most valuable inventions developed by the Board of Invention and Research. By its means the position of a submarine explosion off the coast of Belgium could be found within a few hundred yards by observers on the English coast; passing ships or submarines could also be identified and located. Sound locators were also used on board anti-submarine craft, but at the time of the armistice were for this purpose being superseded by other methods.

Mine construction, laying and sweeping formed the object of many successive improvements. Mines of special construction, which cannot be swept by ordinary means and which explode without actual contact, were used in large numbers in 1918, and were particularly effective against submarines. Various new types of oscillating mines were also developed.

Many of the newer fighting units of the Navy were designed for speeds far in excess of anything that had been previously contemplated; the attainment of the required horse-power was rendered possible by improvements in boiler construction, by the development of oil-firing, and by the invention of the geared turbine. At the present time the horse-power of some of the fastest destroyers equals that of any pre-war Dreadnoughts.

Numbers of strange craft were designed for special purposes. The monitor was used as a floating fortress, and ships without funnels or masts formed cruising aerodromes. The torpedo net was known to be ineffective as well as inconvenient, but some years elapsed before ships were rendered immune to torpedo attacks by a wide outer sheaf of resilient construction. Some protection was first given to mine-sweepers by fitting the vessels with a false prow; the newer mine-sweepers were rendered nearly unsinkable by the provision of numerous bulkheads. The submarine was developed with regard to size, range, and speed. The latest and perhaps the strangest craft was the submarine fitted with a heavy calibre gun which could be fired when all but the muzzle was submerged.

Aircraft.—The rapid progress and expansion of aeronautical science and construction is perhaps the most remarkable achievement of engineering during the war.

In 1909 Blériot flew the Channel. In 1910 Cody won the British Michelin Cup by a flight of 185 miles. The Royal Flying Corps was formed in 1912, and it was decided that the equipment should consist of seventy-two aeroplanes and two airships. The number of aeroplanes available in 1914 was under 200; the number ultimately required proved to be more than 3,000 per month. The aeroplanes which were sent out with the Expeditionary Force in 1914 had a maximum speed of some 80 miles per hour, a rate of climb at ground level of 300 or 400 ft. per minute; they were equipped with engines of 60 to 100 horse-power. In 1918 the fast machine had a maximum speed of 140 miles per hour, a rate of climb at ground level of 2,000 ft. per minute; single-seaters were fitted with engines of 200 to 300 horse-power, and the largest machines were equipped with a power plant developing over 1,300 horse-power. The maximum height attainable had increased from 5,000 to 25,000 ft.

The Atlantic flight has given the measure of the success achieved in the design of long-range bombing machines. Two types were evolved: the fast day bomber, capable of carrying a useful load of about 3,000 lb. at a speed of 130 miles an hour, and the night bomber with a larger load and slower speed. The largest aeroplane manufactured in numbers was the Handley Page V/1500, with a weight of 11 tons and a power plant of 1,300 horse-power. Three days before the armistice two of these machines stood fully equipped waiting for the order to start for Berlin. The largest bombs in use weighed over a ton, and during the war 8,000 tons of explosives were dropped on the enemy. The experience which they had gained in the construction of the high-powered engines required for airship work proved to be a valuable asset for the Germans. Initially also their rate of production, both of aeroplanes and engines, was far superior to ours, and, faced with the menace of otherwise being for a period deprived of machines, we were bound to continue the use of certain standardised types longer than was desirable.

The labour difficulty was overcome by the introduction of a large proportion of female labour, which proved to be very suitable for aeroplane manufacture,

and especially for wing construction. The bulk production of aero-engines presented grave difficulties. Every part had to be made to close limits so as to be interchangeable, and it was necessary to maintain the highest quality with the minimum amount of skilled labour. For a period the supply of magnetos was both inadequate and unsatisfactory. The Germans had acquired practically a monopoly in this direction, and it became essential for us to build up a new industry on the results of careful research and experiment. The fact that under these circumstances a total of 8 million horse-power was produced during the last twelve months of the war represents one of the greatest achievements of engineering organisation.

Synchronised gun firing through the propeller was first brought into use by the enemy, and the success of the Fokker was due, not to superior design, but to this characteristic armament and to the relatively high engine power. On the other hand, throughout the war the only stable machines were British. For observation work, night flying, and flight in fog and cloud the advantages of a stable machine are obvious. On the other hand, instability, inasmuch as it favours rapid and unexpected manœuvres, was for a time regarded as an advantage in aerial fighting, but later experience proved that a well-designed aeroplane could be made stable and yet remain quick and light on the controls.

Seaworthiness, no less than air-worthiness, is required of the seaplane, and this implies a machine of considerable size and weight. Most of the best seaplanes in use in 1918 had a total weight of 4 or 5 tons each, a speed of nearly 100 miles, and engines of about 700 horse-power.

The machines used by the special aeroplane ships were principally small fast scouts, but one type was of sufficient size to carry an 18 in. torpedo. In 1918 seventy aeroplanes were carried by the fleet as part of the regular equipment.

Airships proved to be of great importance in connection with naval work. The smaller non-rigids were used for patrol duty along the coast and convoy service, and by their means a submarine could be detected and attacked while still at a considerable distance below the surface. The success achieved was extensive, and ships convoyed by airships were practically immune from submarine attack. The larger non-rigids served as scouts in naval operations.

The SSZ had a speed of 50 miles and a gross lift of about 2 tons; the North Sea type a lift of 11 tons and a speed of 60 miles.

Compared with the achievements in other directions the record of British work in connection with the development of rigid airships is not entirely satisfactory. In this field, where consistent policy and firmness of purpose were essential, the Admiralty vacillated strangely. The *May-fly*, constructed at Barrow in 1910, was admittedly an experiment, and although an accident ended her career after the first few mooring tests, she had already served her purpose in providing the experience and data necessary for a more perfect construction. Nothing further was done, however, until after the war had started.

In Germany, on the other hand, painstaking plodding had built up success on the ruins of a dozen failures.

Improvements in the rate of climb of aeroplanes and the invention of the incendiary bullet brought an end to the effectiveness of the Zeppelin as a bomber, but as a scout in long range naval operations its influence remained considerable, and the recent successful journey of R34 indicates the possibilities of the rigid airship in times of peace. The useful load increases rapidly with size, and a ship 15 per cent. larger than R34 in linear dimensions could have carried 100 people to America.

What is popularly known as an invention, or an idea of revolutionary importance emanating from one person, has played relatively little part in the recent development of aeronautics. Success has been due to systematic investigation and to the combined effort of many scientific workers, trained designers, and practical constructors. With some exceptions the same holds true in the case of engine construction. Inventions there have been, 8,000 are duly recorded in the files of the Air Inventions Committee, but equipment and armament and accessories appear to have offered most scope for brilliant new departures.

Several inventions notably influenced the course of the war. The successful manufacture of incendiary bullets put an end to the Zeppelin raids, tracer bullets increased the accuracy of aim, and synchronising gear made it possible to fire through the propeller at the rate of nearly 1,000 rounds per minute. A satisfac-

tory self-sealing petrol tank was manufactured after many unsuccessful attempts, and greatly diminished the risk of fire. Much ingenuity was displayed in connection with bomb sighting and navigational instruments. Wireless telephone and directional wireless were introduced. A reliable turn indicator and improved compass made accurate navigation through clouds possible. Armoured aeroplanes were constructed; special machines were also designed for carrying 37 mm. quick-firing guns for use at the Front and against submarines; these guns fired a $1\frac{1}{2}$ lb. high explosive shell.

The increased efficiency of the anti-aircraft artillery and the high rate of climb of the defending machines put a check on daylight aeroplane raids, while at night and in mist both searchlights and guns could be trained on the enemy even if invisible by means of sound directors. A screen of kite-balloons supporting nets formed part of the night defences of London, and justified its existence by the moral effect produced on the enemy pilots.

The use of airships near the fighting zone or within reach of enemy aeroplanes was impossible owing to the inflammable nature of the gas they contained, and in spite of all precautions the loss in kite-balloons was serious. The proposal to replace the hydrogen by helium came from a member of the Board of Invention and Research, and in 1915 experiments were started with a view to the ultimate production of several million cubic feet per month. The boldness of the idea is best emphasised by the fact that at that time it took weeks to obtain the few cubic inches of gas required for the preliminary permeability tests. Progress was accelerated when America came into the war, and at the time of the armistice a supply of 350,000 cubic feet per week was ensured.

The above outline of engineering activities during the war is both incomplete and imperfect. It may, however, serve to emphasise and illustrate the two features which characterised the period and made victory possible.

The first is: Large production, obtained by organisation, standardisation, and co-operation.

The second is: Rapid progress resulting from the stimulus to research and invention and the immediate application of the results obtained.

The required organisation did not arise as a natural development of the pre-war industrial activity: it was called into being by dire necessity and applied with grim determination. Before the war the British nation was anti-militarist, non-scientific, and strongly individualistic. To achieve victory the nation accepted universal conscription, and submitted to the mixture of socialism and tyranny which necessity dictated. Under extreme pressure, scientific knowledge, technical skill, industrial ability, military and naval experience welded into a homogeneous and efficient organisation.

It is easy to disparage the effort or to point to defects, large or small, which tarnish the record, but the fact remains that, whereas in 1914 we were inferior to the enemy in every military asset except moral courage, in 1918 victory came as the result of mastery in practically all the thousand factors on which modern warfare depends.

The organisation involved the direct control of food, every essential raw material, shipping, and transport; further, under the cloak of various euphemisms, it involved the indirect control of all available capital and labour. The capitalist was granted the privilege of receiving and paying the interest on the money required. High wages and the Military Conscription Act ensured an adequate supply of labour in the factories. And these things came to pass, not by tyrannical order of an all-powerful Government, but by the force of a great idea working within the nation.

II.—*Industrial and Economic Reconstruction.*

The peace declaration is the opening of a new act in the world's greatest drama, and the events of the next few years will decide the fate of many generations. The future is always the logical sequence of the past; it is the present which gives direction to the forces which are acting in virtue of the ideals which are operative. The world is emerging from a furnace, and the rigid constitution of civilisation, for a moment plastic, will harden in the mould we form. It is, therefore, the duty of each one of us to attempt to understand the transformation which is going on, and influence it in the right direction.

The principal feature of the day is the insistent craving for better and easier conditions of life; in popular language this is quite inaccurately expressed by a demand for higher wages and less work. The two aims are far from identical; in fact, a little consideration will show that in some respects they are contradictory.

The total remuneration received by a nation is measured by its production, and this law cannot be alterated or affected by legislation or revolution. On the other hand, the share received by a class or an individual is capable of adjustment within certain limits. Thus any class may increase its remuneration either by increasing the total production or by decreasing the remuneration received by the other classes. The capitalist who corners wheat, and the miner who corners coal, are examples of the latter method. No such limitations exist, however, with regard to the face value of the wages paid; by Act of Parliament all wages might be increased arbitrarily twentyfold, but as a result the cost of living would rise in a similar ratio.

Incalculable harm has been done by ignorance and wilful misrepresentation. During a generation the working classes have been told, and have firmly believed, that they receive but a tithe of the value of their work, and that the bulk goes to swell the fortune of the capitalistic class. The actual facts so far as engineering is concerned will be found in the address of my predecessor in this chair. On an average in pre-war days the share of the capitalist was one-ninth that of the workman. The actual position with regard to coal is now known to all. For each ton raised 19*s.* 5½*d.* goes for labour and a total of 2*s.* is paid as royalties, owners' profits, and owners' compensation. It is obvious that the 13*s.* rise in the miner's wages cannot be paid out of profits and royalties amounting to a total of 2*s.*, but the miners, who has been brought up to believe in the fabulous profits of the wicked duke, is quite ready to strike against the owners, the Government, and the laws of arithmetic.

These facts, though clearly established, are not easily credited by the working man; he may have received a penny for what he considers is the manufacture of an article and sees it selling for a shilling in a shop. He forgets that the price must include, not only his wage, but that of the men in the mine, the smelting works, and the rolling mill, who provided the material in the shape required, the wages of the men who built the factory in which he works and made the machine he uses, the wages of transport workers, packers, shop assistants, advertising agents, printer, papermakers, etc., and that, finally, some minute fraction of a farthing might with justice be allotted to the engineer who designed the machine or invented the process. The general position, though similar, cannot, unfortunately, be followed so closely; the limitations, however, are clear. The income of the United Kingdom per head of the population was before the war about 50*l.* If, therefore, the State were run on completely communistic lines, and if under these conditions there were no reduction either in the working hours or the output our wages would average a sovereign a week each, and we could buy our goods at pre-war prices.*

The above considerations indicate that a real improvement in material welfare is necessarily associated with increased production. The needs of mankind are many, its desires are unlimited, and for this reason general over-production need never arise. Many circumstances may, however, lead to uneven balance, and unfortunately, when this occurs, the producers of the commodity which is in excess are penalised, and those responsible for a deficiency are rewarded. The instability is fostered and increased by speculation, and, although it forms the most powerful check on national prosperity, no serious effort has yet been made to apply a remedy.

I am inclined to think that two of the most important problems of our time relate to economic balance and increased production. The solution in the former case is dependent on the statesman, the economist, and the business man, in the latter on the combined efforts of various branches of applied science, and more especially on engineering.

* This statement is optimistic in so far as it does not take account of war losses.

At one time production was directly dependent on muscular effort; it is now mainly influenced by equipment, organisation, and skill. Increased production does not necessarily imply harder work or longer hours; it can be secured by improvements in method and machinery, but only with the willing co-operation of all concerned.

Before the war the Americans were far ahead of us in standardisation and specialised machinery. The American clock and the Ford car are two well-known examples. During the war we adopted and developed these methods. As a result, although the cost of all materials increased considerably, although the wages more than doubled and the profits were more than adequate, the cost was in many cases reduced. Thus the eighteen pounder shell fell from 22*s*. to 12*s*., the Lewis gun from 165*l*. to 62*l*. The importance of standardisation has been fully realised by the manufacturers of this country, and as a result we may hope to see a general reduction in cost.

The economic value of an individual depends exclusively on the nature, quality, and quantity of his output, and his remuneration should correspond to his economic value. The rule is simple, its application would solve most of the problems which vex the present generation, but no scheme has yet been evolved to make its application possible.

There can be no doubt that in this respect our present system is a complete failure. It has been built up casually in the course of the industrial warfare of the last twenty years, and each side, regardless of consequences, has entrenched itself in any position won. The result is a system nearly perfect from the point of view of offence and defence, well arranged for mutual destruction, but, like the trenches in France, unsuitable for use in time of peace.

The minimum wage is beneficial in so far as it prevents sweating, but in two other respects its consequences are most unfortunate. Under the operation of this rule the man whose value is a fraction below the minimum is unemployed and economically unemployable. Further, the minimum wage becomes the standard wage, and the better men are inadequately paid. Both causes lead to decreased production. The weaker or less skilful men drift into enforced idleness, and become a charge to the community under the heading of charity, poor-law, or some newly invented euphemism. The better men, finding extra effort uncompensated, drop to an ever-decreasing minimum. Small output is in most cases the result of inadequate incentive rather than active restriction. Promotion by seniority is an example of a similar cause, producing similar effects in other classes of the community.

Among the professional and business classes the remuneration is proportional to the skill and to the effort; a barrister, an engineer, or a merchant has neither minimum wage nor fixed maximum output, and, the vagaries of chance excepted, generally speaking gets what he is worth. At the two extremes stand riches and starvation, and the economic world can offer no stronger motive forces than the allurements of the one, the fear of the other. There is no absolute reason why the working man should not be offered the same incentives to hard work and progress, but up to the present most efforts have tended in the opposite direction. Any form of payment by result is viewed with indifference or distrust by the Unions, and past experience with piece work explains that attitude. There has been a disposition for employers to make large individual earnings an excuse for cutting rates. Errors in rate fixing may easily arise, and in certain cases special investigation might be necessary, but the advantages of high individual production are so great to both employer and employed that in all cases of doubt the higher rate should be maintained. In this connection the method of time-study first developed by Taylor in America and the various systems of payment by results which have been successfully applied deserve careful consideration.

Another important but difficult subject is the distinction drawn between skilled and unskilled labour. The experience gained during the war has proved that many operations scheduled as skilled work could be effectively performed by women who had only received a few weeks' special instruction. The oft-repeated demand for equal opportunity for all becomes a senseless parrot cry if it does not imply that an individual has the right to undertake better remunerated work if qualified to do so. It is a misconception which leads the skilled worker

to believe that such a concession would reduce his earnings. Just as it is clear that if labourers and skilled men were grouped together at a uniform wage, that wage would necessarily be lower than the present minimum for skilled work, so also the separation of tasks which require but a nominal period of training would increase the rate of remuneration available for the really skilled man.

I have drawn attention to some of the difficulties which must be solved if the country is to emerge from the present crisis prosperous or even solvent. There is little doubt that an elucidation is possible, but it can only be evolved by the honest and intelligent collaboration of all parties concerned, a task rendered difficult or impossible by mutual distrust and class hatred. Class differences there are, and always will be; they exist as the result of breeding, education, and environment, but they do not extend to the fundamental characteristics of humanity. Many dukes and many miners are lazy; most capitalists and most trade unionists are greedy; all men, with a few exceptions, are selfish. The war has shown that lazy, greedy, and selfish men will die or even work for their country in a great exigency, but there is a limit to and a reaction after any profound emotional stimulus, and the present unrest and dissatisfaction are but normal symptoms. A satisfactory economic system can only be based on natural human impulses, and of these the most fundamental is self-preservation, or, more generally, self-interest. Increased production is at the present moment the most pressing national need, but it will become effective only when for every man increased production becomes the talisman by which *his* paper wages can be turned to gold.

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ADDRESS

TO THE

ANTHROPOLOGICAL SECTION

BY

PROF. ARTHUR KEITH, M.D., LL.D., F.R.S.,

PRESIDENT OF THE SECTION.

The Differentiation of Mankind into Racial Types.

FOR a brief half-hour I am to try and engage your attention on a matter which has excited the interest of thoughtful minds from ancient times—the problem of how mankind has been demarcated into types so diverse as the Negro, the Mongol, and the Caucasian or European. For many a day the Mosaic explanation—the tower of Babel theory—was regarded as a sufficient explanation of this difficult problem. In these times most of us have adopted an explanation which differs in many respects from that put forward in the book of Genesis; Noah disappears from our theory and is replaced in the dim distance of time by a 'common ancestral stock.' Our story now commences, not at the close of a historical flood, but at the end of a geological epoch so distant from us that we cannot compute its date with any degree of accuracy. Shem, Ham, and Japeth, the reputed ancestors of the three great racial stocks of modern times—the white, black, and yellow distinctive types of mankind—have also disappeared from our speculations; we no longer look out on the world and believe that the patterns which stud the variegated carpet of humanity were all woven at the same time; some of the patterns, we believe, are of ancient date and have retained many of the features which marked the 'common ancestral' design; others are of more recent date, having the ancient pattern altered in many of its details. We have called in, as Darwin had taught us, the whole machinery of evolution—struggle for existence, survival of the fittest, spontaneous origin of structural variations, the inheritance of such variations—as the loom by which Nature fashions her biological patterns. We have replaced the creative finger by the evolutionary machine, but no one is more conscious of the limitations of that machine than the student of human races. We are all familiar with the features of that racial human type which clusters round the heart of Africa; we recognise the Negro at a glance by his black, shining, hairless skin, his crisp hair, his flattened nose, his widely opened dark eyes, his heavily moulded lips, his gleaming teeth and strong jaws. He has a carriage and proportion of body of his own; he has his peculiar quality of voice and action of brain. He is, even to the unpractised eye, clearly different to the Mongolian native of North-Eastern Asia; the skin, the hair, the eyes, the quality of brain and voice, the carriage of body and proportion of limb to body pick out the Mongol as a sharply differentiated human type. Different to either of these is the native of Central Europe—the Aryan or Caucasian type of man; we know him by the paleness of his skin and by his facial features—particularly his narrow, prominent nose and thin lips. We are so accustomed to the prominence of the Caucasian nose that only a Mongol or Negro can appreciate its singularity in our aryanised world. When we ask how these three types—the European, Chinaman, and Negro—came by their distinctive features, we find that our evolutionary machine is defective; the processes of natural and of sexual selection will preserve and exaggerate traits of body and of mind, but they

cannot produce that complex of features which marks off one racial type from another. Nature has at her command some secret mechanism by which she works out her new patterns in the bodies of man and beast—a mechanism of which we were almost ignorant in Darwin's day, but which we are now beginning to perceive and dimly understand. It is the bearing of this creative or morphogenetic mechanism on the evolution of the modern races of mankind which I propose to make the subject of my address.

Hid away in various parts of the human frame is a series of more or less obscure bodies or glands, five in number, which, in recent times, we have come to recognise as parts of the machinery which regulate the growth of the body. They form merely a fraction of the body—not more than 1/180th part of it; a man might pack the entire series in his watch-pocket. The modern medical student is familiar with each one of them—the pituitary body, about the size of a ripe cherry, attached to the base of the brain and cradled in the floor of the skull; the pineal gland, also situated in the brain, and in point of size but little larger than a wheat-grain; the thyroid in the neck, set astride the windpipe, forms a more bulky mass; the two suprarenal bodies situated in the belly, capping the kidneys, and the interstitial glands embedded within the substance of the testicle and ovary, complete the list. The modern physician is also familiar with the fact that the growth of the body may be retarded, accelerated, or completely altered if one or more of these glands becomes the seat of injury or of a functional disorder. It is thirty-three years now since first one woman and then another came to Dr. Pierre Marie in Paris seeking relief from a persistent headache, and mentioning incidentally that their faces, bodies, hands, and feet had altered so much in recent years that their best-known friends failed to recognise them. That incident marked the commencement of our knowledge of the pituitary gland as an intrinsic part of the machinery which regulates the shaping of our bodies and features. Dr. Marie named the condition acromegaly. Since then hundreds of men and women showing symptoms similar to those of Dr. Marie's patients have been seen and diagnosed, and in every instance where the acromegalic changes were typical and marked there has been found a definite enlargement or tumour of the pituitary body. The practised eye recognises the full-blown condition of acromegaly at a glance, so characteristic are the features of the sufferers. Nay, as we walk along the streets we can note slight degrees of it—degrees which fall far short of the border-line of disease; we note that it may give characteristic traits to a whole family—a family marked by what may be named an acromegalic taint. The pituitary gland is also concerned in another disturbance of growth—giantism. In every case where a young lad has shot up, during his late 'teens,' into a lanky man of seven feet or more—has become a giant—it has been found that his pituitary gland was the site of a disordered enlargement. The pituitary is part of the mechanism which regulates our stature, and stature is a racial characteristic. The giant is usually acromegalic as well as tall, but the two conditions need not be combined; a young lad may undergo the bodily changes which characterise acromegaly and yet not become abnormally tall, or he may become—although this is rarely the case—a giant in stature and yet may not assume acromegalic features. There is a third condition of disordered growth in which the pituitary is concerned—one in which the length of the limbs is disproportionably increased—in which the sexual system and all the secondary sexual characters of body and mind either fail to develop or disappear—where fat tends to be deposited on the body, particularly over the buttocks and thighs—where, in brief, a eunuchoid condition of body develops. In all of these three conditions we seem to be dealing with a disordered and exaggerated action of the pituitary gland; there must be conditions of an opposite kind where the functions of the pituitary are disordered and reduced. A number of cases of dwarfism have been recorded where boys or girls retained their boyhood or girlhood throughout life, apparently because their pituitary gland had been invaded and partly destroyed by tumours. We shall see that dwarfism may result also from a failure of the thyroid gland. On the evidence at our disposal, evidence which is being rapidly augmented, we are justified in regarding the pituitary gland as one of the principal pinions in the machinery which regulates the growth of the human body and is directly concerned in determining stature, cast of features, texture of skin, and character of hair—all of

them marks of race. When we compare the three chief racial types of humanity—the Negro, the Mongol, and the Caucasian or European—we can recognise in the last named a greater predominance of the pituitary than in the other two. The sharp and pronounced nasalisation of the face, the tendency to strong eyebrow ridges, the prominent chin, the tendency to bulk of body and height of stature in the majority of Europeans, is best explained, so far as the present state of our knowledge goes, in terms of pituitary function.

There is no question that our interest in the mechanism of growth has been quickened in recent years by observations and discoveries made by physicians on men and women who suffered from pituitary disorders, but that a small part of the body could influence and regulate the growth and characterisation of the whole was known in ancient times. For many centuries it has been common knowledge that the removal of the genital glands alters the external form and internal nature of man and beast. The sooner the operation is performed after birth the more certain are its effects. Were a naturalist from a unisexual world to visit this earth of ours it would be difficult to convince him that a brother and a sister were of the same species, or that the wrinkled, sallow-visaged eunuch with his beardless face, his long tapering limbs, his hesitating carriage, his carping outlook and corpulent body, was brother to the thick-set, robust, pugilistic man with the bearded face. The discovery that the testicle and ovary contain, scattered throughout their substance, a small glandular element which has nothing to do with their main function—the production of genital cells—was made seventy years ago, but the evidence which leads us to believe that this scattered element—the interstitial gland—is directly concerned in the mechanism of growth is of quite recent date. All those changes which we may observe in the girl or boy at puberty—the phase of growth which brings into full prominence their racial characteristics—depend on the action of the interstitial glands. If they are removed or remain in abeyance the maturation of the body is both prolonged and altered. In seeking for the mechanism which shapes mankind into races we must take the interstitial gland into our reckoning. I am of opinion that the sexual differentiation—the robust manifestations of the male characters—is more emphatic in the Caucasian than in either the Mongol or Negro racial types. In both Mongol and Negro, in their most representative form, we find a beardless face and almost hairless body, and in certain Negro types, especially in Nilotic tribes, with their long, stork-like legs, we seem to have a manifestation of abeyance in the action of the interstitial glands. At the close of sexual life we often see the features of a woman assume a coarser and more masculine appearance.

Associated with the interstitial glands, at least in point of development, are the suprarenal bodies or glands. Our knowledge that these two comparatively small structures, no larger than the segments into which a moderately sized orange can be separated, are connected with pigmentation of the skin dates back to 1894, when Dr. Thomas Addison, a physician to Guy's Hospital, London, observed that gradual destruction of these bodies by disease led to a darkening or pigmentation of the patient's skin, besides giving rise to other more severe changes and symptoms. Now it is 150 years since John Hunter came to the conclusion, on the evidence then at his disposal, that the original colour of man's skin was black, and all the knowledge that we have gathered since his time supports the inference he drew. From the fact that pigment begins to collect in and thus darken the skin when the suprarenal bodies become the seat of a destructive disease we infer that they have to do with the clearing away of pigment, and that we Europeans owe the fairness of our skins to some particular virtue resident in the suprarenal bodies. That their function is complex and multiple, the researches of Sharpey-Schafer, of T. R. Elliott, and of W. B. Cannon have made very evident. Fifteen years ago Bulloch and Sequeira established the fact that when a suprarenal body becomes the site of a peculiar form of malignant overgrowth in childhood, the body of the boy or girl undergoes certain extraordinary growth changes. The sexual organs became rapidly mature, and through the framework of childhood burst all the features of sexual maturity—the full chest, muscularity of limbs, bass voice, bearded face and hairy body—a miniature Hercules—a miracle of transformation in body and brain. Corresponding changes occur in young girls—almost infants in years—with a tendency to assume features which characterise the male.

Professor Glynn [1] has recently collected such cases and systematised our knowledge of these strange derangements of growth. There can be no doubt that the suprarenal bodies constitute an important part of the mechanism which regulates the development and growth of the human body and help in determining the racial characters of mankind. We know that certain races come more quickly to sexual maturity than others, and that races vary in development of hair and of pigment, and it is therefore reasonable to expect a satisfactory explanation of these characters when we have come by a more complete knowledge of the suprarenal mechanism.

During the last few years the totally unexpected discovery has been sprung upon us that disease of the minute pineal gland of the brain may give rise to a train of symptoms very similar to those which follow tumour formation of the cortex of the suprarenal bodies. In some instances the sudden sexual prematurity which occurs in childhood is apparently the immediate result of a tumour-like affection of the pineal gland. We have hitherto regarded the pineal gland, little bigger than a wheat-grain and buried deeply in the brain, as a mere useless vestige of a median or parietal eye, derived from some distant human ancestor in whom that eye was functional, but on the clinical and experimental evidence now rapidly accumulating we must assign to it a place in the machinery which controls the growth of the body.

We come now to deal with the thyroid gland, which, from an anthropological point of view, must be regarded as the most important of all the organs or glands of internal secretion. Here, too, in connection with the thyroid gland, which is situated in the front of the neck, where it is so apt to become enlarged and prominent in women—I must call attention to a generalisation which I slurred over, when speaking of the pituitary and suprarenal glands. Each of these glands throws into the circulating blood two sets of substances—one set to act immediately in tuning the parts of the body which are not under the influence of the will, to the work they have to do when the body is at rest and when it is making an effort; another set of substances—which Prof. Gley has named morphogenetic—has not an immediate but a remote effect; they regulate the development and co-ordinate the growth of the various parts of the body. Now, so far as the immediate function of the thyroid is concerned, our present knowledge points to the gland as the manufactory of a substance which, when circulating in the body. regulates the rate of combustion of the tissues; when we make a muscular effort, or when our bodies are exposed to cold, or when we become the subjects of infection, the thyroid is called upon to assist in mobilising all available tissue-fuel. If we consider only its immediate function it is clear that the thyroid is connected with the selection and survival of human races. When, however, we consider its remote or morphogenetic effects on growth its importance as a factor in shaping the characteristics of human races becomes even more evident. In districts where the thyroid is liable to that form of disease known as goitre it has been known for many a year that children who were affected became cretins—dwarf idiots with a very characteristic appearance of face and body.[2] Disease of the thyroid stunts and alters the growth of the body so that the subjects of this disorder might well be classed as a separate species of humanity. If the thyroid becomes diseased and defective after growth of the body is completed then certain changes, first observed by Sir William Gull in 1873, are set up and give rise to the disordered state of the body known as myxœdema. 'In this state,' says Sir Malcolm Morris,[3] 'the skin is cold, dry and rough, seldom or never perspires, and may take on a *yellowish* tint; there is a bright red flush in the malar region. The skin as a whole looks transparent; the hair of the scalp becomes scanty; the pubic and axillary hair, with the eyelashes and eyebrows, often falls out; in many cases the teeth are brittle and carious. All these appearances disappear under the administration of thyroid extract.' We have here conclusive evidence that the thyroid acts directly on the skin and hair, just the structures we employ in the classification of human races. The influence of

[1] *Quart. Journ. of Med.*, 1912, vol. v., p. 157.

[2] The story of the discovery of the action of the thyroid gland is told by Prof. G. M. Murray, *Brit. Med. Journ.*, 1913, II., p. 163.

[3] *Brit. Med. Journ.*, 1913, I., p. 1038.

the thyroid on the development of the other systems of the body, particularly on the growth of the skull and skeleton, is equally profound. This is particularly the case as regards the base of the skull and the nose. The arrest of growth falls mainly on the basal part of the skull, with the result that the root of the nose appears to be flattened and drawn backwards between the eyes, the upper forehead appears projecting or bulging, the face appears flattened, and the bony scaffolding of the nose, particularly when compared to the prominence of the jaws, is greatly reduced. Now these facial features which I have enumerated give the Mongolian face its characteristic aspect, and, to a lesser degree, they are also to be traced in the features of the Negro. Indeed, in one aberrant branch of the Negro race—the Bushman of South Africa—the thyroid facies is even more emphatically brought out than in the most typical Mongol. You will observe that, in my opinion, the thyroid—or a reduction or alteration in the activity of the thyroid—has been a factor in determining some of the racial characteristics of the Mongol and the Negro races. I know of a telling piece of evidence which supports this thesis. Some years ago there died in the East End of London a Chinese giant—the subject, we must suppose, of an excessive action of the pituitary gland—the gland which I regard as playing a predominant part in shaping the face and bodily form of the European. The skeleton of this giant was prepared and placed in the Museum of the London Hospital Medical College by Col. T. H. Openshaw, and any one inspecting that skeleton can see that, although certain Chinese features are still recognisable, the nasal region and the supra-orbital ridges of the face have assumed the more prominent European type.

There are two peculiar and very definite forms of dwarfism with which most people are familiar, both of which must be regarded as due to a defect in the growth regulating mechanism of the thyroid. Now, one of these forms of dwarfism is known to medical men as Achondroplasia, because the growth of cartilage is particularly affected, but in familiar language we may speak of the sufferers from this disorder of growth as being of the 'bulldog breed' or of the 'dachshund breed.' In the dachshund the limbs are greatly shortened and gnarled, but the nose or snout suffers no reduction, while in the bulldog the nose and nasal part of the face are greatly reduced and withdrawn, showing an exaggerated degree of Mongolism. Among achondroplastic human dwarfs both breeds occur, but the 'bulldog' form is much more common than the 'dachshund' type. The shortening of limbs with retraction of the nasal region of the face—pug-face or prosopia we may call the condition—has a very direct interest for anthropologists, seeing that short limbs and a long trunk are well-recognised racial characteristics of the Mongol. In the second kind of dwarfism, which we have reason to regard as due to a functional defect of the thyroid, the Mongolian traits are so apparent that the sufferers from this disorder are known to medical men as 'Mongolian idiots'—for not only is their growth stunted, but their brains also act in a peculiar and aberrant manner. Dr. Langdon Down, who gave the subjects of this peculiar disorder the name 'Mongolian idiots' fifty-five years ago, knew nothing of the modern doctrine of internal secretions, but that doctrine has been applied in recent years by Dr. F. G. Crookshank [4] to explain the features and condition of Mongoloid imbecile children. Some years ago [5] I brought forward evidence to show that we could best explain the various forms of anthropoid apes by applying the modern doctrine of a growth-controlling glandular mechanism. In the gorilla we see the effects of a predominance of the pituitary elements; in the orang, of the thyroid. The late Professor Klaatsch tried to account for the superficial resemblances between the Malay and the orang by postulating a genetic relationship between them; for a similar reason he derived the Negro type from a gorilline ancestry. Occasionally we see a man or woman of supposedly pure European ancestry displaying definite Mongoloid traits in their features. We have been in the habit of accounting for such manifestations by the theory, at one time very popular, that a Mongoloid race had at one time spread over Europe, and that Mongoloid traits were atavistic recurrences. An examination of the human remains of ancient Europe

[4] The *Universal Medical Record*, 1913, vol. iii., p. 12.
[5] *Journ. of Anat. and Physiol.*, 1913.

yields no evidence in support of a Turanian or Mongol invasion of Europe.

All of these manifestations to which I have been calling your attention—the sporadic manifestation of Mongoloid characters in diseased children and in healthy adult Europeans, the generic characters which separate one kind of ape from another, the bodily and mental features which mark the various races of mankind—are best explained by the theory I am supporting—namely, that the conformation of man and ape and of every vertebrate animal is determined by a common growth-controlling mechanism which is resident in a system of small but complex glandular organs. We must now look somewhat more closely into the manner in which this growth-regulating mechanism actually works. That we can do best by taking a glimpse of a research carried out by Bayliss and Starling in the opening years of the present century. They were seeking to explain why it was that the pancreas poured out its digestive juice as soon as the contents of the stomach commenced to pass into the first part of the duodenum. It was then known that if acid was applied to the lining epithelial membrane of the duodenum, the pancreas commenced to work; it was known also that the message which set the pancreas into operation was not conveyed from the duodenum to the pancreas by nerves, for when they were cut the mechanism was still effective. Bayliss and Starling solved the puzzle by making an emulsion from the acid-soaked lining epithelium of the duodenum and injecting the extract of that emulsion into the circulating blood. The result was that the pancreas was immediately thrown into activity. The particular substance which was thus set circulating in the blood and acted on the pancreas and on the pancreas alone, and which thus served as a messenger or hormone, they named secretin. They not only cleared up the mechanism of pancreatic secretion, but at the same time made a discovery of much greater importance. They had discovered a new method whereby one part of the human body could communicate with and control another. Up to that time we had been like an outlandish visitor to a strange city, who believed that the visible telegraph or telephone wires were the only means of communication between its inhabitants. We believed that it was only by nerve fibres that intercommunication was established in the animal body. Bayliss and Starling showed that there was a postal system. Missives posted in the general circulation were duly delivered at their destinations. The manner in which they reached the right address is of particular importance for us; we must suppose that the missive or hormone circulating in the blood and the recipient for which they are intended have a special attraction or affinity for each other—one due to their physical constitution—and hence they and only they come together as the blood circulates round the body. Secretin is a hormone which effects its errand rapidly and immediately, whereas the growth or morphogenetic hormones, thrown into the circulation by the pituitary, pineal, thyroid, suprarenals, and genital glands, act slowly and remotely. But both are alike in this: the result depends not only on the nature of the hormone or missive, but also on the state of the local recipient. The local recipient may be specially greedy, as it were, and seize more than a fair share of the manna in circulation, or it may have 'sticky fingers' and seize what is not really intended for local consumption. We can see that local growth—the development of a particular trait or feature—is dependent not only on the hormones supplied to that part, but also on the condition of the receptive mechanism of the part. Hence we can understand a local derangement of growth—an acromegaly or giantism confined to a finger or to the eyebrow ridges, to the nose, to one side of the face, and such local manifestations are not uncommon. It is by a variation in the sensitiveness of the local recipient that we have an explanation of the endless variety to be found in the relative development of racial and individual features.

Some ten years after Starling had formulated the theory of hormones, Professor W. B. Cannon, of Harvard University, piecing together the results of researches by Dr. T. R. Elliott and by himself, on the action of the suprarenal glands, brought to light a very wonderful hormone mechanism—one which helps us in interpreting the action of growth-regulating hormones. When we are about to make a severe bodily effort it is necessary to flood our muscles with blood, so that they may have at their disposal the materials necessary for work—oxygen and blood-sugar, the fuel of muscular engines. At the beginning

of a muscular effort the suprarenal glands are set going by messages passing to them from the central nervous system; they throw a hormone—adrenalin—into the circulating blood, which has a double effect; adrenalin acts on the flood-gates of the circulation, so that the major supply of blood passes to the muscles. At the same time it so acts on the liver that the blood circulating through that great organ becomes laden with blood-sugar. We here obtain a glimpse of the neat and effective manner in which hormones are utilised in the economy of the living body. From that glimpse we seem to obtain a clue to that remarkable disorder of growth in the human body known as acromegaly. It is a pathological manifestation of an adaptational mechanism with which we are all familiar. Nothing is better known to us than that our bodies respond to the burden they are made to bear. Our muscles increase in size and strength the more we use them; increase in the size of our muscles would be useless unless our bones also were strengthened to a corresponding degree. A greater blood supply is required to feed them, and hence the power of the heart has to be augmented; more oxygen is needed for their consumption, and hence the lung capacity has to be increased; more fuel is required—hence the whole digestive and assimilative systems have to undergo a hypertrophy, including the apparatus of mastication. Such a power of co-ordinated response on the part of all of the organs of the body to meet the needs of athletic training, presupposes a co-ordinating mechanism. We have always regarded such a power of response as an inherent property of the living body, but in the light of our growing knowledge it is clear that we are here dealing with a hormonic mechanism, one in which the pituitary gland is primarily concerned. When we study the structural changes which take place in the first phase of acromegaly,[6] we find that not only are the bones enlarged and overgrown in a peculiar way, but so are the muscles, the heart, the lungs, the organs of digestion, particularly the jaws; hence the marked changes in the face, for the form of the face is determined by the development of the upper and lower jaws. The rational interpretation of acromegaly is that it is a pathological disorder of the mechanism of adaptational response; in the healthy body the pituitary is throwing into the circulation just a sufficiency of a growth-regulating substance to sensitise muscles, bones, and other structures to give a normal response to the burden thrown on the body. But in acromegaly the body is so flooded with this substance that its tissues become hypersensitive and respond by overgrowth to efforts and movements of the slightest degree. It is not too much to expect, when we see how the body and features become transformed at the onset of acromegaly, that a fuller knowledge of these growth mechanisms will give us a clue to the principles of race differentiation.

There must be many other mechanisms regulated by hormones with which we are as yet totally unacquainted. I will cite only one instance—that concerned in regulating the temperature of the body. We know that the thyroid and also the suprarenal glands are concerned in this mechanism; they have also to do with the deposition and absorption of pigment in the skin, which must be part of the heat-regulating mechanism. It is along such a path of inquiry that we expect to discover a clue to the question of race colour.

This is not the first occasion in which the doctrine of hormones has been applied to biological problems at the British Association. In his Presidential address to the Zoological Section at Sheffield in 1910 Professor G. C. Bourne applied the theory to the problems of evolution: its bearing was examined in more detail in an address to the same section by Professor Arthur Dendy during the meeting at Portsmouth in 1911. At the meeting of the Association at Newcastle in 1916 Professor MacBride devoted part of his address to the morphogenetic bearings of hormones. Very soon after Starling formulated the hormone theory, Dr. J. T. Cunningham applied it to explain the phenomena of heredity.[7] Nay, rightly conceived, Darwin's theory of Pan-genesis is very much of the same character as the modern theory of hormones.

[6] See Keith, *Lancet*, 1911, ii., p. 993; 1913, i., p. 305.

[7] Dr. J. T. Cunningham, *Proc. Zoo. Soc. London*, 1908, p. 434.

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SECTION I: BOURNEMOUTH, 1919.

ADDRESS

TO THE

PHYSIOLOGICAL SECTION

BY

PROFESSOR D. NOËL PATON, M.D., F.R.S.,

PRESIDENT OF THE SECTION.

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An Aspect of Protein Metabolism.

I. INTRODUCTION.

To find oneself President of a Section of the British Association is an intimation that one has joined the ranks of the veterans and a warning that one's days of active work are numbered.

But, while one accepts the situation with some twinges of regret, one is consoled by the thought that a long association with physiology has enabled one to take a wider general survey than one did in one's younger days, to see more clearly the bearing of one part upon another and to recognise some of the dangers to which we, as investigators and teachers, are exposed.

It has often been urged that physiology, the study of Life, cannot possibly be an exact science in the same way as physics and chemistry are. My old friend, Prof. P. G. Tait, used to twit me about my mind being debauched by the so-called science of biology.

I am not quite sure what the charge that biology is not an exact science really means. But if it means that in it direct methods of measurement are

not possible, then I am inclined to reply that in many of the phenomena of molecular physics, including chemistry, such direct methods are still wanting, or have only recently been devised, while in physiology the whole trend of the science has been to devise graphic or self-registering methods, and to exclude more and more the fallacies of observation through the senses. I need only refer to the precision which has been given to the study of the action of enzymes within recent years. It is only when our study of life involves, as it must often involve, the consideration of consciousness, that we are thrown back upon observational methods, that the personal element is introduced as a disturbing factor, and that our results are open to many different interpretations. Of course the same fallacy may invade the investigation of many of the vital manifestations not involving consciousness, but the fault then is in the observer. It is so difficult to avoid forcing the interpretation which appeals to us. But it should be recognised that unless the evidence collected, when set down quite simply and without comment, leads others to the same conclusion as that to which we have arrived, we are not justified in dressing it up in order to secure it more ready acceptance. In doing so, we cease to be scientific men and become special pleaders.

And here I should like to say that the most scientific men I have met have not been Bachelors of Sciences, or those trained in the schools. I think, like poets, they are born, not made. They must not only have the overpowering desire for knowledge and the keen zest in its pursuit, but they must have that coldly critical spirit which enables them to know if they are pursuing a reality or a phantasy.

Yet this dressing up of one's view so as to make it convincing is one of the most tempting of crimes—a crime which all of us, usually unconsciously, have doubtless committed in our time and will go on committing. And the worst of it is that the abler the exponent, the greater is the harm done. Every part of physiology affords startling examples of this. That which first occurs to me is the theory of secretion of urine, upon which a recent writer frankly takes up one hypothesis and with great ability defends it through many pages, as a conclusion to be unreservedly accepted. It is so difficult to say, 'the evidence is inconclusive, to give the verdict of "Not proven."' The same thing is seen in the old fight between the exponents of the two main theses of colour vision, neither of which is necessarily right. An attractive interpretation, boldly stated by an able advocate, is apt to seize the imagination even of a critical physiologist and to lead to an abrogation of judgment and a blind acceptance. Especially is this the case when the work is not in our own special line and when it is announced by a due flourish of trumpets and is supported by the invention of more or less incomprehensible Greek words devised by some classical colleague. Dangerous and unscientific as is this championing of one interpretation of a series of observations or experiments, it has not infrequently helped forward the advance of the science. It has often stimulated other workers and led on to the true solution of the problem—witness the fascinating work and the able deductions drawn from it by Heidenhain or lymph formation which stimulated Starling to subsequent investigations thus leading to a better understanding of the facts which Heidenhain had observed. Witness too the admirable study of cutaneous sensibility by Head and Rivers and their interpretation of the results, uncritically accepted by some, but which stimulated others to restudy the subject and to indicate simpler interpretations of the observations, and these have reacted again to induce further work upon the subject. A consideration of these dangers in the physiological inquiry helps us to understand how seldom any line of investigation goes straight to the goal: almost universal is the zigzag forward progression, at one time many points off the straight line in one direction—at another just as many off in another.

This devious manner of progress, perhaps more marked in the work of previous generations, is still manifest in many of the modern lines of advance, largely as a result of too ready acceptance of the conclusions arrived at from insufficient experimental data. Witness the to-and-fro swing of our conception of the significance of adrenalin in the body.

But the older workers were so hampered by insufficient methods that many of the conclusions accepted as final should have been taken as simply provisional.

II. Protein Metabolism.

A consideration of the present position of our knowledge of the metabolism of protein in the body, and of the way in which we have arrived at it, is a striking illustration of this zigzag advance, what I have elsewhere described as tacking to windward.

It was only towards the end of the eighteenth century that the true nature of the nitrogenous constituents of plants and animals was recognised, although Boerhaave in 1732 had indicated their identity. Fourcroy and Scheele and Berthollet did much to advance our knowledge of their composition.

1. Proteins as a Source of Energy.

It was Liebig, early in the nineteenth century, who really first emphasised the primary importance of the albuminous constituents of the body. It was he who first clearly taught the value of these proteins as constituents of the food in building up the living body. It was he who first pointed out that by their combustion in the body energy required for work is liberated—although he made the mistake of concluding that it was all supplied by proteins.

Is it to be wondered at that in those days of inadequate knowledge of physiology and of imperfect methods of investigation, he had to content himself with a purely theoretical consideration of the subject, and that he failed to disabuse his mind of the idea of the necessary co-operation of some vital force or spirit to protect the albumen from oxidation during muscle rest. Physiologists even at the present day are too apt to seize upon such metaphysical abstraction as a cloak for ignorance!

The formulation by Liebig of the theory that the oxidisation of proteins is the sole source of the energy liberated in muscular work is perhaps the most striking example of the danger of the bold statement by a great scientific authority of a conclusion unverified by experiment.

For years it dominated all study of the physiology of nutrition and to the present day it influences the practice of trainers of athletes. It was in vain that Voit recorded his experiments, which showed that muscular work does not increase the output of urea, which it should have done had Liebig's theory been correct.

Certainly Voit's experiments were themselves imperfect, since he failed to carry his observations beyond the day in which exercise was taken.

It is a striking commentary on this credulity of physiologists that the experiment which struck the first blow to the general acceptance of Liebig's teaching was that of Fick and Wislicenus in their ascent of the Faulhorn, an experiment which for years held a prominent place in every textbook of Physiology, an experiment which every physiologist of to-day will agree was absolutely worthless, inasmuch as these observers took protein food on the day before the experiment and were excreting its products next day, inasmuch as they stopped collecting the urine on the night of the ascent, and inasmuch as their estimation of the work done left out of consideration the respiratory disturbances in the ascent.

Still, I remember how, as a student, I was taught that this experiment had overthrown the teaching of Liebig. Its influence is shown by the fact that Pflüger took up the defence of Liebig's teaching. You all remember the records of the very lean dog fed on the leanest horse-flesh in Bonn and doing work in drawing a load the energy for which was liberated from proteins—because the dog had nothing else from which to liberate it!

You all remember the well-known experiment of Argutinsky by which he thought to show that over 90 per cent. of the energy of the work of hill-climbing came from proteins. At that time I ventured to point out that Argutinsky was losing weight even before the exercise, that he was in a condition of semi-starvation and that therefore, when any extra call for energy was made, it had to be got from the protein of the body, since he was a lean young man. The chief value of his work was in showing that any increased excretion of nitrogen occurs, not on the day of the exercise, but on the two succeeding days.

Since that time the methods of investigating the processes of metabolism have enormously advanced, and the combination of the study of the respiratory

exchange along with the excretion of nitrogen has enabled a definite decision to be obtained as to the utilisation of the three proximate principles during rest and during muscular work.

As everyone knows, it has been demonstrated that while carbohydrates must be considered as the most readily available food of the body, it is equally true that the direct or indirect oxidation of the amino acids formed from the proteins of the food or of the tissues on the one hand and of facts on the other are also valuable sources of energy.

2. Proteins in Growth and Repair.

The advance in our knowledge of the way in which protein is used in the construction and repair of tissues shows a less devious course. First came the recognition of changes of the crude protein of the food to more diffusible, and, as was later shown, simpler condition. Then came the discovery by Kutscher, Seeman and Cohnheim of the more complete breakdown into the constituent amino acids, a recognition of the purpose of the breakdown to yield the constituent 'Bausteine' for use as required by each tissue, and lastly the elaborate work upon the special significance and potentialities of each of these.

Some of these amino acids must be supplied as such, and if certain of these, which may occur only in minute amounts in the body tissues, are withheld, growth is rendered impossible. They become the limiting factor.

Other amino acids, glycol for example, may be formed in the body.

Not the least important of the amino acids are the diamino acids—

Lysin,
Histidin,
Arginin,

which are so abundant in the protein in which combines with nuclic acid in nuclei of cells. That lysin is essential for growth has been for long well established. Histidin and arginin resemble one another closely in the constitution of their molecules, but while histidin has the iminazole ring, arginin has the guanidin molecule as the end of the chain.

Experiments recorded by Ackroyd and Hopkins[1] tend to show that in the absence of these two diamino acids growth of young white rats is arrested, there is a loss of body weight, but that the addition of both or either of these is sufficient to restore the rate of growth. Such observations seem to indicate that they are among the amino acids which are essential and which must be supplied in the food.

The fact that the addition of either one or other is sufficient to restore growth led these investigators to suggest that in metabolism each one can be converted into the other. The safer conclusion seems to me to be that both of them can yield some substance which is necessary for growth and normal metabolism.

The same workers further give experiments to show that in the absence of these substances, the excretion of allantoin falls and that it is again increased when one or other or both are added to the diet. They suggest that arginin and histidin probably constitute the most readily available raw material for the synthesis of the purin ring in the animal body.

It must be remembered that Abderhalden and Julius Schmidt failed to get evidence of the formation of allantoin from histidin in the dog. As yet the relationship of these bodies to purin metabolism cannot be considered as definitely established. Investigations upon chickens which excrete such large quantities of purin nitrogen should yield more conclusive results.

The possible source of creatin, methyl-guanidin acetic acid, from histidin has been considered by Ditmann and Welcker on purely theoretical grounds which need not now be considered.

Arginin is a much more abundant constituent of most proteins than is histidin. The characteristic of the arginin molecule is the presence of guanidin. It is guanidin-amino-valeric acid.

In the protein of ox-flesh it occurs to the extent of about 11 per cent., so that taking the protein of muscle at 20 per cent., there is present in ox-flesh some 2 per cent. of arginin. This contains about 40 per cent. of guanidin, so

[1] *Biochem. Jour.* x., 1916, 543.

that in the arginin alone there is no less than 0·8 per cent. of combined guanidin and 0·57 per cent. guanidin nitrogen (72 per cent. N.), or, taking the total nitrogen of flesh at 3·7 per cent., no less than 15 per cent. of the total nitrogen.

From cat's muscle Miss Henderson [2] recovered an average of 0·56 per cent. of total guanidin, *i.e.*, 0·4 per cent. guanidin nitrogen, with 3·7 per cent. of total nitrogen in the muscle. The guanidin nitrogen then amounted to nearly 10·4 per cent. of the total.

3. Specific Action of Constituents of Proteins.

An important aspect of the metabolism of proteins is the physiological activity of some of their products of disintegration.

The specific dynamic action of protein in stimulating the rate of metabolism and increasing heat production, first demonstrated by Rubner, has been shown by Lusk to be due to the action of their constituent amino acids.

Some of Mansfield's work strongly suggests that this action may be controlled by the thyroid gland, but into this question it is impossible to enter at present.

Now the possible importance of one product of disintegration of protein, the guanidin moiety of the arginin molecule, has so far received no attention.

1. *Sources.*

Its real significance has been too readily ignored on account of the demonstration of the formation of urea in the metabolism of arginin. But while Kossel and Dakin [3] showed that this urea formation goes on in the liver, they did not find the same evidence of the change in muscle. Thompson [4] after the administration of arginin by the mouth and subcutaneously to dogs, recovered very varying amounts in the form of urea and got a marked increase in the excretion of ammonia. He was forced to conclude that arginin stimulates nitrogenous metabolism, in this way acting as the more recent work of Luck has shown that so many amino acids act, and rendering any conclusion as regards the complete conversion to urea impossible.

More recently Inonye,[5] in perfusion experiments through the liver and in autolysis experiments, has observed an increase in creatinin after the addition of arginin.

Thompson,[6] shortly before his tragic and untimely death, published a series of experiments which proved fairly conclusively that arginin alone, and still more markedly when given along with methyl citrate, distinctly increases the output of total creatinin, mainly by increasing the output of creatin.

In the face of such experiments it must be concluded that a certain part at least of the guanidin moiety of arginin escapes conversion into urea and ultimately forms creatin.

That the guanidin in arginin, creatin and other substances may be primarily formed from non-protein nitrogen is indicated by the demonstration by Burns [7] of the formation in the developing chick. He found that the amount of guanidin in the egg showed a steady increase to the twelfth day of incubation and only after this date did creatin appear.

In considering the possible origin of the guanidin thus formed, one is almost forced to look to the cholin part of the lecithin molecule as the only possible source.

The formation of guanidin or at least of creatin, methyl-guanidin acetic acid, from cholin is not purely hypothetical, for Reisser [8] has not only considered it on theoretical lines—that it can be produced by a union of cholin with urea—but he has actually produced evidence to show that in rabbits the creatin of muscle is increased after the administration of cholin.

[2] *J. of Phys.* 52, p. 1, 1918.
[3] *Ztsch. f. phys. Chem.* 41, p. 321, and 42, p. 181, 1904.
[4] *J. of Phys.* 33, p. 106, 1905-06.
[5] *Ztsch. f phys. Chem.* 81, p. 71, 1912.
[6] *J. of Phys.* 51, p. 347, 1917.
[7] *Biochem. Jour.* 19,
[8] *Ztsch. f. phys. Chem. Bd.* 86, p. 435, 1913.

Baumann, Hines and Marker [9] in a short note state that by perfusing with choline and urea in the dog, they got an increase of the creatin in muscle.

If cyanamid instead of urea took part in the reaction methyl-guanidin might be directly formed, the ethyl group of the cholin being oxidised away and two methyls removed.

Of course in the mammals and in the chick after hatching the arginin in the protein of the food and the creatin in the flesh, when it is eaten, must serve as an ample supply of the guanidin that is required, so ample in fact that probably a very considerable part of arginin is at once decomposed by arginase into urea.

2. *Methyl-guanidin a normal constituent of the body.*

Methyl-guanidin is a normal constituent of flesh and of liver as was shown by Smordinzew. Miss Henderson [10] found in the muscle of cats an average of 0·0839 per cent. of free guanidin or methyl-guanidin. It occurs in normal human urine and in that of the dog and horse.[11] In the blood of normal dogs (200 cases) it was in hardly detectable quantities.[12]

In tetania parathyreopriva the increase in the guanidin content of the blood is accompanied by an increased excretion in the urine and in the idiopathic tetany of children and of adults (two cases) guanidin as di-methyl-guanidin (Sharpe) in amounts easily demonstrable, appears in the urine. Methyl-guanidin, like uric acid, thus seems to be partly excreted as such, and partly when in larger quantities to undergo some change.

3. *Physiological Action of Guanidin.*

Guanidin and its methyl derivative, which in future I shall speak of together as guanidin, are substances of great pharmacological activity. Their action was first investigated by Gergens and Baumann in 1876. They described in frogs fibrillar twitching of the muscles due to a peripheral action and tonic extensor spasms due to an action on the spinal cord. They point out that in mammals the tonic spasms are more marked than the fibrillar twitching of the muscles.

Subsequent investigators have confined their attention chiefly to the peripheral action and considerable discussion has arisen as to the exact point of action of the substance.

When we were investigating tetania parathyreopriva, Dr. Burns was engaged on an investigation, following up the suggestion of Pakelharing, upon the possible relation of the guanidin part of the creatin molecule to the tone of muscle.

The extraordinary similarity of the symptoms produced with those of experimental tetany suggested to us the possibility that the condition of tetany might be related to some disturbance of the guanidin metabolism, and led to a more careful investigation of the action of guanidin and methyl-guanidin.

We had already arrived at the conclusion that the tetany is due to a toxic substance in the blood, since the symptoms can be temporarily removed by bleeding and transfusing with normal sodium chloride solution, a fact which cannot be explained on the view that the symptoms are due to a decrease in the calcium of the blood as had been suggested by McCallum.

We found that the administration of guanidin and methyl-guanidin produced symptoms identical with those of parathyreoidectomy. There was the same direct stimulation of the outgoing spinal neurons to the muscles, leading to tremors, jerkings and general convulsions and when large doses were directly applied to the spinal cord a paralytic condition similar to that which sometimes supervenes in tetania parathyreopriva. There was the same increased excitability of the nerves to electrical stimulation, followed, after large doses, by a curare-like action, a condition also observed in clinical tetany after convulsion.

Koch had described the occurrence of guanidin with other bases in the urine of the dog after removal of the parathyreoids. In our series of experiments

[9] *J. of Biol. Chem.* 24, p. xxiii., 1916.

[10] *Jour. of Phys.*

[11] *Barger. Simpler Natural Bases*, p. 79.

[12] Burns and Sharpe, *Quart. J. of Exp. Phys.*, vol. , 1915.

Burns and Sharpe found a most marked increase in the guanidin or methyl-guanidin content of the blood (*loc. cit.*).

The method is long and tedious and there is considerable chance of loss, although in test analysis it was found to give a good return of the added base. But the differences between the guanidin content of normal blood and of blood after parathyreoidectomy and in children suffering from tetany was found to be very marked.

Wishart[13] further found that the muscles of the frog immersed in the serum from the blood of dogs and cats after parathyreoidectomy frequently manifested the tremors and the characteristic change in contraction which are produced by the action of guanidin. The possibility of using this biological test is, however, limited by the fact that the muscles of frogs kept in confinement for some time do not respond to guanidin as was shown by Langley.

The conclusion we drew from our experiment was that the parathyreoids somehow regulate the metabolism of guanidin in the body and that in doing so they may play a part in regulating the tone of the skeletal muscles.

It is by the continued activity of the efferent neurons of the cord that this tone is maintained, and it is upon these muscles that guanidin acts. Possibly, when the amount of guanidin is small, this action is facilitated by the increased excitability of the nerve endings, and that, when the amount is increased, the effect of its overaction upon the centre may be masked by the onset of the curare like action on the terminations.

This is not the place, however, to discuss the question of the nerve channels by which impulses concerned in the maintenance of tone reach the muscle.

Detoxication of Guanidin.

As I have already indicated, guanidin remains active after methylation, but when it, or its methyl compound, is linked to acetic acid, as in creatin, it becomes inert.

Burns has also found that linked to glucose it loses much of its toxicity and Camis states that when rubbed up with muscle solutions of guanidin becomes inert.

I have all along felt that the significance of creatin must be looked for in its guanidin moiety. Creatin itself is inert, although Maxwell[13] has recorded an exciting action in the cortex cerebri.

In spite of Pekelharing's results I do not think that there is evidence that the creatin content of muscles is associated directly with the maintenance of muscle tone.

Certainly when the nerve to a muscle is cut, the tone is at once lost, and yet, until the marked structural changes of advanced degeneration appear, the finding of Cathcart and Henderson and Nöel Paton[15] are that the creatin content does not markedly decrease.

While freely admitting the validity of much of the evidence that an increase in tone may be accompanied by an increase of the creatin content of the muscles and an increased excretion of creatinin, there seems to me to be no indication of how the increase in creatin modifies the tone. The administration of creatin subcutaneously does not do so. And hence the only possible explanation must be that the increased tone is associated with an increased amount of guanidin in the blood and that the increase in the creatin is secondary to this—the result of an attempt to remove any excess of guanidin. The evidence in favour of this will be presently considered.

As regards the relationship of creatin to guanidin, two possibilities have to be considered, either that (1) creatin is the source of free guanidin, or (2) creatin is formed to fix an excess of guanidin and to detoxicate it. It may then be excreted as creatin or creatinin, or the creatin may be used in the resynthesis of such molecules as arginin or histidin.

1. The view that creatin is a source of methyl-guanidin is favoured by the ease with which it is oxidised outside the body by HgO to methyl-guanidin. But on the other hand there is no evidence that this occurs in the body. Even

J. of Phys. 52, p. 70, 1918.

in large doses creatin is non-toxic and I have found that when injected into parathyreoidectomised animals it does not accelerate the onset of symptoms, while the injection of even very small doses of guanidin does so. If creatin were a source of guanidin it should act in the same way.

2. The second view that creatin fixes and detoxicates guanidin is supported by the following evidence :

1. Miss Henderson [16] finds that after parathyreoidectomy there is an increase of the creatin content of the muscle and a decrease, not only of the free guanidin, but also of the total guanidin along with the increase of free guanidin in the blood recorded by Burns and Sharpe. The decrease in the free guanidin corresponds closely with the increase in the creatin guanidin and suggests that a process of linking is occurring. But on the other hand the more marked fall which occurs in the total guanidin of muscle in proportion to the total nitrogen seems to show that there is either (1) an increased elimination of guanidin from the muscle to the blood, or (2) a decreased taking up from the blood. In either of these ways the concentration of guanidin in the blood necessary to enable it to manifest its stimulating action on the central nervous system might be brought about. As is well known muscle takes amino acids from the blood and stores them at a higher concentration. Folin has shown that it also takes up creatin and urea, and Mrs. Cathcart has shown that it even takes ammonia salts from the blood.

2. Jaffe [17] had shown that glycocyamin, guanidin acetic acid, is methylated in the body and so converted to creatin. This was confirmed by Dorner.[18] But neither of these succeeded in getting an increase in the creatinin of the urine after the injection of methyl-guanidin. As Riesser points out the toxicity of this substance makes it almost impossible to get results in this way.

Thompson,[19] however, got a distinct increase in the creatinin output in the dog and in the creatin output in the duck after parenteral injection of guanidin carbonate.

Some recent unpublished work by Wishart in my laboratory shows that after injecting guanidin into dogs and hens the creatin content of the muscle is markedly increased.

I give a tabular view of his remarks :

Creatin per cent. in Muscles before and after injection of guanidin sulphate.

—	Before	After
Cat 1	·470	·566
„ 2	·589	·639
„ 3	·540	·553
Dog 1	·324	·393
Hen 1	·460	·426 Control—No quantities injected
„ 2	·522	·672
„ 3	—	·643
„ 4	—	·626

These observations seem to me to be of very great importance since they indicate quite clearly that creatin may be formed from guanidin.

This formation of creatin from guanidin may explain the failure to recover all the guanidin when it is injected even although it is a substance which resists so strongly the action of all oxidising agents.

Pommerenig found that guanidin given in small quantities was completely excreted as such in thirty-six hours, but in large doses only 30 per cent. was recovered.

[17] *Ztsch. f. Phys. Chem.* 48, p. 430, 1906.
[18] *Ztsch. f. Phys. Chem.* 52, p. 225, 1907.
[19] *J. of Phys.* 51, p. 360, 1917.

Burns (loc. cit.) after the intra-muscular injection of 0·64 gm. of guanidin hydrochloride, recovered in the next seventeen hours only about 25 per cent., more than half of which had become methylated.

That the whole process of the formation of creatin is carried on in the muscles and that the liver has absolutely nothing to do with it may now be considered as quite definitely settled.

Experiments recorded by Mackie and myself [18] on the effects of exclusion of the liver from the circulation in geese and ducks seem to be conclusive on this point, and they are confirmed by the result of Towles and Voegtlin.[19]

The fate of creatin will be considered later.

Significance of Urinary Creatin.

As Folin and others have clearly shown, the power of storing creatin in muscle is very limited, and any excess in the food is apt to appear in the urine either as creatin or possibly to some extent as creatinin.

In a man of 65 kilos, the skeletal muscles weigh about 30 kilos, with, say, 0·3 per cent. of creatin, in all some 90 grms.

Now if anything like 1 gm. of creatin be given it tends to appear as such in the urine.

The taking of even a moderate amount of flesh leads to the appearance of creatin in the urine and although, as Orr and Burns [20] have shown, that creatin is not necessarily all derived from the creatin of the flesh but probably from some other precursor, nevertheless a considerable amount comes directly from the creatin. Evidently the power which the body possesses of dealing with creatin is very limited.

At present I do not intend to discuss the question of the possible conversion or non-conversion of creatin to creatinin. It has been an unfortunate battle because it has drawn attention from the much more important question—what is the significance of creatin?—the question on which I have tried to throw a fresh light in considering its relationship to guanidin, but one which has to be further prosecuted in order to decide whether creatin is simply a waste product on the way to excretion or whether it may be used in the body.

To me it seems that these questions may best be solved by their study in animals in which they are least complicated by the creatin-creatinin controversy. Fortunately in birds, as was long ago shown by Meissner, we have a group of animals which excrete creatin as an end product and only at most traces of creatinin. Just as their power of changing uric acid to urea is small so that most of their nitrogen comes away in the first form, so their power of changing creatin to creatinin—if it is possessed by any animals—is negligible. My demonstration of this in 1910 [21] has since been fully confirmed by Thompson.

The results then obtained seemed to show that creatin injected subcutaneously does not undergo any change in the avian body, but that it is excreted as such. In three experiments, creatin injected under the skin appeared in the urine to the extent of 91 per cent., 109 per cent., 83 per cent. Such observations do not, however, prove that the creatin formed in the ordinary course of metabolism is all excreted in this form.

Since creatin is at least ten times more abundant in muscle than in any other tissue of the body, and since muscle so greatly exceeds all other tissues in bulk, muscle must be considered *the* source of urinary creatin.

The amount of creatin daily excreted must be the result of the liberation of so much creatin from the muscles, and since the amount of creatin in muscle is so constant, this liberation must be covered by a corresponding formation, or a corresponding decrease in the bulk of muscle.

It is well known that in fasting in mammals creatin appears in the urine, and that in the fasting condition in man the combined excretion of creatin and creatinin shows a comparatively small change in spite of the decrease in the rate of protein catabolism as indicated by the excretion of total nitrogen.

In the rabbit on the other hand Dorner's results show an increased total

[18] *J. of Physiol.*, vol. p.
[19] *J. of Biol. Chem.* 10, p. 479, 1911-12.
[20] *Bio. Chem. J.*, 10, p. 495, 1916.
[21] *J. of Physiol.*, vol. 1910.

protein catabolism with an enormous increase of the excretion of creatin and creatinin due almost entirely to the creatin.

In geese and ducks I found that there is a rise in the excretion of creatin during fasting which varies with the condition of nutrition of the bird, at the beginning of the fast being small where the nutrition is good, and larger where the animal has been on a low diet and is thin before the fast started. Thus in a young, well-fed goose during a fast of three days there was practically no change in the excretion of creatin, while in a poorly nourished bird fed on maize the creatin excretion on the second day of the fast had increased sevenfold.

Myers and Fine [22] from their observations upon fasting dogs come to the conclusion that the increased amount of creatin execreted during a fast is all derived from the creatin which was in the flesh at the commencement of the fast. They find in short fasts a slight increase in the creatin content of muscle and in longer fasts a decrease. A series of unpublished analyses made for me by Dr. Cathcart of the muscles of the salmon kelts and of feeding salmon show that after the prolonged fast of many months the creatin is increased in relation to the total nitrogen of the muscle.

Creatin and Total Nitrogen in Muscle. Thick and Thin of Salmon.

Total Nitrogen.			Creatin.	
Thin.	Thick.		Thin.	Thick.
5 Salmon (feeding).				
3·57	3·61		0·241	0·224
		Creat.—T.N.	6·7	6·2
5 Kelts (prolonged fast).				
3·13	3·18		0·241	0·279
		Creat.—T.N.	7·7	8·7

Myers and Fine's conclusions have been severely criticised by Stanley Benedict and Osterberg.[23]

These investigators maintain that creatin is a material which is being constantly formed during the course of a fast, that only that part which is not metabolised is excreted and that the amount excreted is no index of the amount of muscle tissue catabolised.

They base their conclusions upon experiments upon dogs rendered completely diabetic by phloridzin. Having shown that during fasting such dogs excrete large amounts of creatin—as had been already demonstrated by Cathcart and Taylor—they gave washed fibrin or washed flesh, both creatin free, in sufficient quantity to nearly cover the loss of nitrogen, and because the creatin excretion under these conditions is still maintained they conclude that it is not the result of the breakdown of muscle tissue.

Certainly when these proteins are fed to the animal an abundant source of the guanidin required for creatin formation has been furnished, and it appears to me to be no proof whatever that in fasting the creatin in the urine is not the result of the catabolism of muscle setting free a proportionate amount of creatin.

But it raises another and very interesting question: granting that the creatin is liberated by muscle breakdown why does it appear in the urine in the absence of carbohydrates and in conditions of imperfect oxygenation of the blood?

This question will be dealt with later.

In 1910 I looked upon creatin as part of the muscle molecule, if one may be allowed to use such a term, and considered that the amount of creatin excreted was a measure of muscular disintegration.

This view that creatin is an integral part of the muscle molecule and that it is liberated only upon death has now been adopted by Folin.[24]

[22] *J. of Biol. Chem.* 14, p. 18, 19.
[23] *J. of Biol. Chem.* 18, p. 195, 1914.
[24] *J. of Biol. Chem.*, 17, p. 500, 1914.

The evidence is by no means conclusive. The only experimental work recorded is that of Urano which cannot be considered as in any way satisfactory.

Some recent experiments as yet unpublished by Wishart tend to show that the creatin exists as such in the muscles, and not as an integral part of its substance.

In these experiments a frog was killed by a blow on the head and instantly one hind leg still *in situ* was frozen hard in a mixture of ice and salt and the whole of the extraction process carried out near the freezing point up to the hydrolysis of the filtrate.

Frozen.	Unfrozen.
·070	·076
·063	·072
·058	·071

Folin's demonstration of the accumulation of injected creatin in muscle also seems to me to indicate that in part at least it may exist in a free state.

It may well be that in fasting, when the muscle proteins are used as a source of energy or are carried to more essential organs, the free creatin may be liberated proportionately to the break-down and execreted without the reduced muscle tissue showing any percentage decrease.

In 1910 I argued against the possibility of there being an increased production of creatin in fasting and I still think the argument is valid. Since the creatin nitrogen must come from somewhere, any increase in the excretion of creatin should be accompanied by a decrease in the excretion of nitrogen in other forms. This is not the case, in fact the relationship is in the opposite direction—the increase of creatin being accompanied rather by an increase in 'other nitrogen.'

On the other hand, I then failed to appreciate the possibility that the increase in the creatin might be the result of a failure of its metabolism in some other direction.

Neither Folin nor any other worker has found an immediate increase in the nitrogen excretion after the administration of creatin, and it thus seems unlikely that any metabolic change occurs in it *when about to be excreted*. But its metabolism may be in the process of anabolism, and I shall later adduce evidence that creatin may be used in the building up of the muscle material, e.g., as a source of the guanidin in arginin.

But whether the increased excretion of creatin in fasting is due to its liberation from muscle substance as it breaks down (Myers and Fine), or to its being a product of the disintegration of muscle substance (Folin), or to there being a failure to resynthesise the creatin into muscle substance, the amount of creatin in the urine will indicate the amount of muscle disintegrated and not resynthesised, i.e., *the actual breakdown of muscle*.

Three conditions may occur in the course of a fast:

1. The break-down may involve not only muscle but also the proteins in other tissues of the body.
2. It may involve muscle almost exclusively.
3. It may involve muscle, but the nitrogenous constituents may be used for the repair of other tissues, as is so well seen in the fasting salmon, where materials from the muscles are transported to and laid down in the growing ovary.

The first condition occurs in the early days of a fast, especially in well-fed animals where the liver and other organs are rapidly losing weight.

The third condition appears later in a fast when all surplus protein has been metabolised, and when the organs essential to life have to be kept going at the expense of the muscles.

The muscles of the goose or duck contain about 0·134 per cent. of nitrogen in creatin and 3·6 per cent. altogether. Hence, in the break-down of muscle, one part of nitrogen must be in creatin for twenty-seven parts of total nitrogen.

If the nitrogen of the urine is in this proportion, it is muscle tissue which is bearing the brunt of the disintegration due to fasting.

If the total nitrogen is above this proportion to the creatin nitrogen, the protein-rich tissues other than muscle are taking their share in the cata-

bolic process. If the creatin nitrogen is above this proportion, then the conclusion seems inevitable that proteins derived from muscle are being retained and used for the maintenance of non-muscular tissues. This method I applied to the study of the metabolism in the course of fasting in geese and ducks, and showed how it gave direct information of the condition of the exchanges in the body

Its application to the study of the progress of protein metabolism in fasts in man and other mammals does not necessitate the adoption of any theory of the relationship of creatin to creatinin.

Folin's most recent view[22] of the sources of these two substances is that when muscle tissue dies, the creatin is set free as a post-mortem product, and that in times of stress, *e.g.*, in fever, fasting, etc., the break-down into creatinin is accompanied by a break-down into creatin. He even admits the possible conversion of small amounts of creatin to creatinin and vice versa.

Accepting this conception, it is manifest that the creatinin and creatin excretion should in the mammal give the same index of the course of metabolism in fasting, as the excretion of creatin alone does in the bird. This I illustrated in 1910 by applying the method to the study of several recorded facts in man.

Creatin as an Anabolite.

The evidence as to whether creatin is a possible anabolite, whether it can be used for the reconstruction of muscle substances, may now be considered.

It was Folin who first suggested that it may act in this way, or, as he put it, may act as a sort of food. He arrived at this view on account of the disappearance of creatin when fed by the mouth, but the demonstration by Mellanby and Twort[25] that creatin is broken down in the alimentary canal, deprives these experiments of much of their value.

Lefmann[26] after subcutaneous injection in dogs, recovered only a small amount of creatin in the urine, and although his conclusion that there is no conversion to creatin has been criticised by Van Hoogenhuyze and Verploegh, there seems to me to be an increasing amount of evidence in favour of Folin's theory.

Cathcart[27] showed the important fact that the administration of carbohydrates to a fasting man stops the excretion of creatin and that, where carbohydrates cannot be used, as in diabetes, creatin appears in the urine.[28]

The explanation that the result is solelv due to the presence of diacetic acid is, as Cathcart and Orr showed, not tenable.

The work of Loewi in 1902, as Lülhje pointed out, showed that while the amino-acid products of pancreatic digestion of proteins when eaten along with carbohydrates bring about an actual retention of nitrogen, when fed with fats alone they fail to do so.

The indications, then, seem very clear that carbohydrates are essential for the synthesis or re-synthesis of the protein molecule and, if creatin is a potential anabolite yielding the necessary guanidin, the presence of carbohydrates is probably essential for its use in this way and in their absence it must be excreted.

This view, as far as it concerns the total nitrogen and muscle, I ventured to formulate as far back as 1887, and I then attempted to represent it diagramatically.[29]

The adoption of this view does not invalidate the idea that the formation of creatin is primarily to de-toxicate an excess of free guanidin. The same thing is seen in the behaviour of lecithin, which is manifestly an anabolite, but which seems to have the power of rendering the toxic cholin innocuous.

[25] *J. of Phys.* 44, p. 43, 1912.
[26] *Ztsch. f. Phys. Chem.*, 57, p. 476, 1908.
[27] *J. of Phys.*, 39, p. 299, 1909.
[28] *J. of Phys.*, 41, p. 276, 1910.
[29] *J. of Phys.*, 33, 1905, p. 1

The Relationship of Creatin and Creatinin.

The importance of the lengthy and voluminous discussion on the relationship of creatinin to creatin seems to me to have acquired an exaggerated importance.

In the bird the creatin in the urine represents the ordinary overflow of the creatin from muscle which is not used for reconstruction. In mammals this is represented by creatinin, but when the disintegrative changes are increased or the anabolic processes interfered with, then creatin appears along with creatinin.

The non-conversion, or only small conversion of creatin injected or taken by the mouth, to creatinin, does not appear to be opposed to the view that the latter is formed from the former. The total formation of creatinin in man is only about 1 grm. per diem, one ninetieth of the total creatin in the body. If this small conversion is all the body has daily to provide for, it is not to be expected that the demand for a sudden increased conversion will be met, and hence it seems only natural to expect that unconverted creatin will escape if it is administered even in small amounts. The normal occurrence of creatin in the urine of young children seems to indicate that its conversion to creatinin is a function somewhat late in development.

There is some evidence that the power of conversion is different in different individuals. Thus we found that after a pound of beefsteak with about 1·7 grm. of creatin as creatinin, one member of the teaching staff showed a rise of 0·53 grm. of creatinin and 0·2 grm. of creatin, another a rise of 0·49 grm. of creatinin and 0·177 of creatin, while two others showed no rise in the creatinin, one showing an increase of 0·425 grm. and the other of 0·213 grm. in the creatin excreted.

The question may be asked, why should the neutral creatin be converted into the strongly alkaline creatinin? The relative solubility of the two substances is a possible explanation of this. Creatin is soluble in parts of water, creatinin is soluble in parts.

Creatin Investigations Old and New.

It is extraordinary how, in spite of the enormous amount of work which has been done upon the subject, our knowledge of the significance of creatin has advanced so little since Meissner's really wonderful investigations in 1868, now so entirely ignored. In spite of the unsatisfactory methods then available, he concluded that in the bird creatin and not creatinin occurs in the urine, that its amount is increased by giving meat or injecting creatin, that it is higher on a protein rich diet such as liver than on a protein poor diet such as grain, and that it is increased in fasting.

From his observations on mammals he concluded that urea and creatinin have different origins, thus anticipating Folin's theory of endogenous and exogenous metabolism, and that, in the study of creatin metabolism, feeding with meat must be avoided. He found that creatinin was excreted in the smallest amounts in animals gaining weight on a protein poor diet.

The work upon creatin metabolism which has been carried on in many laboratories during the past few years has been somewhat fragmentary and difficult to combine into an organic whole, but I believe that it can be so combined and that a more or less reasonable explanation can be given by the recognition of the fact that its significant part is the guanidin nucleus, and that it is in connection with this that its real meaning is to be found, that by the formation of creatin free guanidin is detoxicated and rendered available for synthesis into muscle substance.

Folin's method has made the investigation of creatin a very simple matter, but so far no reliable and rapid method has been devised for the determination of guanidin or methyl guanidin. Hence our knowledge of the metabolism of these substances is still very defective. Probably it will not be possible greatly to enlarge it until better methods of analyses have been devised.

To look back upon the progress of knowledge of any branch of science even upon one so limited in range as that of protein metabolism, is like looking back upon the records of ancient voyages of discovery. There are the same dreams of enchanted islands far to the West—the islands of the Hesperides;

the same imaginary accounts of their position and of their characters, too often accepted as all sufficing; the same spirit of scepticism driving some bolder spirit to embark in his cockle shell boat and sail forth on the ocean of discovery, to find if these imaginings have any reality the same picking up of some small fragments of flotsam and jetsam, hinting that somewhere out there the land is really to be found; the same failure to advance due to the badly equipped ships or to imperfect seamanship; and again the imagination playing round the few observations and reconstructing images as unreal as those which they displace. Again, as the ships' compasses and means of navigation improve, another attempt pressed further and ending in the discovery of land indeed—but of some barren reef simply telling that not there lie the islands sought for, and warning the next explorer that some other course must be laid. Again the study of the records of past failures and the attempt to decide what must be the next line of advance. Then the next voyage is started, the course set south-west instead of north-west, till some fine morning another barren rock is sighted. But now the mariner starboards his helm and off goes the ship on another tack till haply the promised island lies ahead—not *one* island but an archipelago, the exploration of which is to be the work of many followers of the original discoverer.

In the discovery of the true position and general features of nutrition of the metabolism of the proteins, Liebig, Voit, Pflüger, Zuntz, and Rubner have been the great pioneers. To us is left the smaller task of exploring and charting the archipelago they discovered, of investigating each separate island and of so making complete the great work of our predecessors. And although the voyages before us may be less arduous than theirs, it is still well before embarking to let our imagination play forward along our course, to consider the difficulties and dangers of the voyage, and to see that our boat is adequately equipped.

When we are once afloat, let us go forward in the spirit of true discoverers, not obsessed with preconceived ideas of what we are going to find, but with minds open to all that may present itself so that, whatever happens as we go onward, we may add some small trifle to the general store of knowledge.

And what of all those who sailed forth and suffered shipwreck or returned empty? Are they to be pitied? *No*, if they were of the real stuff, all they asked and what they got was—

I must go down to the seas again, to the lonely sea and the sky,
And all I ask is a tall ship and a star to steer her by;
And the wheel's kick and the wind's song and the white sail's shaking,
And a grey mist on the sea's face, and a grey dawn breaking.

The joy of sailing upon the ocean of discovery—that to the man of science is the joy of life.

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SECTION K: BOURNEMOUTH, 1919.

ADDRESS

TO THE

BOTANICAL SECTION

BY

SIR DANIEL MORRIS, K.C.M.G., M.A., D.Sc., D.C.L., LL.D., F.L.S.

PRESIDENT OF THE SECTION.

It was with a feeling of great responsibility that I accepted the invitation to preside at the meeting of the Botanical Section of the British Association and to follow in the footsteps of the distinguished men who have occupied this position, and especially at this time when the circumstances of the country and the Empire call so largely for the co-operation of all interested in botanical research and the application of science to reconstruction after the war. It is well to bear in mind that while the justification of science depends upon its general application to the affairs of life, we must not forget that the first conditions of its assured progress is the recognition of the patient and exhaustive investigations of the laws of Nature which are immutable. The consolation is that what we wrest from Nature holds good for all time.

During the great war which has now happily been brought to a close it has been made abundantly clear that in Botany, as in other applied sciences, we must rely in future less on chance individual effort and initiative. We must co-operate our efforts and organise them at every stage, bearing in mind that we shall always require the services of the worker in pure science to solve those larger problems of national importance which confront us. We must be armed by science, or we shall be placed at a great disadvantage in the great struggle now before us. We are told that it is absolutely necessary for the prosperity and safety of the country that the development of the resources of the Empire and the production of our industries must be on a scale greatly in excess of anything we have hitherto achieved. As an Imperial people it is our duty to develop our resources to the fullest extent.

Fortunately, a great change is taking place in the attitude of the Government and the State towards Science, and it is noticeable also in the relations of Science to industry and commerce.

Since we last met we have lost a number of devoted workers in Botany. Professor Daniel Oliver was the highly esteemed and valued coadjutor of both the Hookers, and his conscientious devotion to duty and unrivalled knowledge of flowering plants raised him to a distinguished position among botanists of all countries.

Another Kew man, George Edward Massee, the well-known mycologist and plant pathologist, has left an enduring mark on British mycology.

Clement Reid occupied a unique position in relation to geology and botany. His book on 'The Origin of the British Flora' was an important addition to botanical literature. Jointly with Mrs. Reid he produced a quarto monograph of the Pliocene Flora. Ethel Sargent, the President of this Section in 1913, was one of the most gifted and distinguished workers in Botany. She was the first woman to serve on the Council of the Linnean Society. Her name will long be associated with the well-supported and well-reasoned theory of the origin of Monocotyledons.

In the early part of last year another gap in the ranks of women botanists

occurred in the death of Dr. Ethel de Fraine. She investigated the seedling structure of the Cactaceæ and the rare fossil stem *Sutcliffia*. She was also deeply interested in ecological work, and correlated the structural features of plants with morphological and ecological problems.

Professor Pearson, the founder of the National Botanic Garden at the Cape, accomplished much valuable work in a short life. He was an exceptionally good explorer, and his contributions to botany ranged over a wide field. His important investigation of *Welwitschia* enabled him to amplify and extend Sir Joseph Hooker's classic memoir on that genus. He also threw much new light on the Gnetales.

In the death of Philippe de Vilmorin the cause of science and genetics has lost a good friend. He was the grandson of Louis de Vilmorin, one of the first who had inklings of the work of heredity, and rendered great service in the improvement of the sugar beet.

Mr. F. Ducane Godman, in his great work 'Biologia Centrali-Americana,' comprising sixty-three large quarto volumes, for which he bore the whole expense, has an enduring monument of his learning and generosity. He belonged to the small but distinguished class of Naturalists who devote their time and resources to promote research from pure love of Science.

Sir Edward Fry's life-long interest in British Botany ranged in later years over the wide field of cryptogamy. He is said to have 'wished, at times, that men of science could be induced to state and argue the debatable matters with all due forms and production of evidence as matters of fact are debated in a court of law.'

Apart from those who have passed away in what may be called the course of nature, a sad aspect of the losses sustained in the great war is the death of so many brave young men for whom it was anticipated that a bright and successful career was open in the domain of Science. Their names are inscribed on the Roll of Honour, and we gratefully bear them in memory. I ask you to stand for a moment to renew our fellowship with the immortal dead.

From the point of view of the scientific exploration of the resources of the Empire it is satisfactory to note that the publications dealing with the floras of tropical and sub-tropical countries have been continued. These involving, as they do, so much labour and forethought are of more than passing interest from the fact that they serve to reveal the distribution of plants that may eventually prove of great economic value. A close investigation of tropical plants is necessary, as allied species or varieties of one and the same species sometimes differ greatly as regards their economic value. An instance of this kind has been observed in the case of the so-called 'bastard logwood' of Jamaica. The botanical characters of this are almost identical with those of the common logwood, but its physiological properties are so different that it is worthless for commercial purposes. A parallel case is furnished by *Robinia pseudo-acacia*, the wood of which is described by Sargent as being reddish, greenish-yellow or white according to the locality, but the yellow and white varieties occur side by side in at least one locality. The carefully prepared 'Flora Capensis,' of which eight volumes have been issued under the auspices of Kew, is now nearing completion. In this connection it is interesting to learn that the Government of the Union of South Africa has recently appointed an Advisory Committee for a systematic survey of the characteristic botany of that portion of the Empire. Another very important contribution to systematic botany is the 'Flora of Tropical Africa.' Of this six volumes have been published. The grasses, which will occupy the ninth and last volume, comprise a description of 400 species, or a little over one-third of the grass flora of tropical Africa.

In the Western Tropics the 'Flora of Jamaica,' containing a systematic account, with illustrations, of the flowering plants of that interesting island and published by the Trustees of the British Museum, is making good progress. A 'Flora of Bermuda,' with all genera illustrated by text figures, as in the 'Flora of Jamaica,' was issued last year by Dr. N. L. Britton, of the New York Botanical Gardens. About 8·7 per cent. of the total native flora of 709 species is regarded as endemic.

To supplement Hooker's great 'Flora of British India' the second part of Gamble's 'Flora of Madras' appeared last year. Duthie's 'Flora of the Gangetic Plain" is still in hand. Of Maiden's comprehensive monograph 'A

'Critical Revision of the Genus Eucalyptus,' thirty-five parts, comprising 181 species, have, so far, been issued.

Digressing for the moment, I would mention that British Guiana, with an area equal to that of Great Britain, on the mainland of South America, is full of interest, but its rich and abundant flora, extending from an extensive coast line to the high lands of the interior, with the Kaieteur falls and the remarkable Roraima Mountain rising to over 8,000 feet, is little known to the world at large. There is, also, the fertile and easily accessible island of Trinidad, at the mouth of the Orinoco, which has been a British Colony for more than a hundred years. Although the necessary material is conveniently at hand in the local herbaria, brought together with great care during the last thirty years, neither of these portions of the Empire has, as yet, published a handy working flora from which their special botanical and economical resources might be ascertained. In these days a systematic exploration of our tropical possessions and the publication of the results in an accessible form should serve as the first step in their fuller development.

Of interest from another point of view is a new supplement of 'Index Kewensis' now ready for the press. This invaluable work of reference was originally prepared at the urgent request of Darwin, who undertook the cost of producing it. The Bentham Trustees have lately issued a complete index to the plates and names of plants that appear in the thirty volumes of 'Hooker's Icones Plantarum.'

Further, it is worthy of note that the Royal Horticultural Society is arranging, with the help of Kew and the British Museum (Natural History), to undertake to bring out a new edition of Pritzel's 'Iconum Botanicorum Index.' The original work, indispensable to a botanical and horticultural library, contained 107,000 entries. It is estimated that, at least, an additional 125,000 references will appear in the new edition.

This may be an appropriate occasion to refer to the new branch of botany which has lately come into prominence as one of the results of the devotion to nature study and the contemplation of the characteristic features of vegetation as we find it distributed over the earth's surface. Ecology is capable of enormously extending the outlook of botany, and it has so largely added to the interest of field work that we may wonder that the phenomenon of vegetation so long displayed before our eyes had not suggested its sociological aspects long ago. Ecology has its Society and Journal, and it bids fair to fully establish itself in the household of botany. It is hoped it will mitigate some of the admitted drawbacks of purely laboratory work and revive the old Natural History spirit of former days. As pointed out by Thiselton-Dyer, it is to this spirit that we owe the Darwinian theory which rested on every point on a copious basis of fact and observation made in field and forest.

In describing the principal forms of plant communities the first requisite is to become familiar with the species and their distribution in relation to their habitat. This neighbourhood is noteworthy for the opportunities it offers for the study of the natural vegetation of calcareous soils, of the heathlands of the Bagshot sands, as well as of an interesting series of aquatic and marsh plants. The presence of many of the Southern elements of the British flora enumerated by Stapf is also of interest. Among these, to mention a few, are *Simethis bicolor*, *Lotus hispida*, *Gladiolus illyricus*, *Ludwigia palustris*, *Lobelia urens*, *Erica ciliaris*, and *Pinguicula lusitanica*.

The phenomenal spread of a comparatively new marsh grass (*Spartina Townsendii*) along certain portions of the South Coast deserves careful study. It is supposed to be a hybrid between *S. stricta* and *S. alternifolia*. It is claimed to be pre-eminent among halophytes on account of the extraordinary vigour with which it spreads over mud flats and eventually forms meadows to be measured by thousands of acres in the neighbourhood of Southampton Water and Poole Harbour. It is a question whether it may not develop into a serious menace to navigable waters. On the other hand, it may prove capable of being utilised in suitable localities as a reclaiming agent. Its economic value in providing material for paper-making or as food for cattle may also receive attention. It is unnecessary to enter into further details, as Professor Oliver, who has kept this grass under observation for many years, has kindly consented to give an address summarising the results.

The critical study of British plants was supposed to be an exhausted field, but with the necessary insight and careful and critical observation there is much work still to be done. Exchange clubs are active, and additions to local floras are continually being made. New species, varieties, and hybrids are published from time to time. As an instance, *Potamogeton upsaliensis*, hitherto only known in Sweden, has recently been found in this neighbourhood. Hybrid orchids are being keenly studied, and the occurrence of hybrids in this and other classes of plants opens a wide and interesting field of investigation.

A much-desired piece of work is a continuance of Starkie Gardner's interesting investigation of the fossil flora of the Bagshot beds so well shown in the Bournemouth and adjoining cliffs. Some of these have proved exceptionally rich in remains of tropical and sub-tropical plants. Among the genera claimed to be represented are *Acacia, Smilax, Lygodium, Gleichenia, Myrica, Eucalyptus, Araucaria, Diospyros, Nipadites, Sequoia,* and a palm (Iriartea), now only found in tropical America. So far, in regard to these plant remains, we may say with La Place : 'What we know is but little : what we do not know is immense.'

After an interval unprecedented in the history of the British Association we meet once more under its high authority so that the leaders in science and men of affairs with wide and deep experience may take council together and discuss the latest results of scientific investigations. We have everything to gain from a free exchange of experience and ideas. This is a time when science does well to renew its touch with daily life both for its own sake no less than for the sake of true progress. It is recognised that the enormous advance in the material comfort and the prosperity of our race during the last century has been due to the application of science. Nevertheless, in the newer times which we are now entering upon we shall require all our energy and all available scientific knowledge to win through to success. It is encouraging to realise that since we met at Newcastle in 1916 there has been a truly remarkable progress in every branch of science. Also, a fuller recognition of the value of science and education as means whereby the material interests of the world may be enlarged.

My distinguished predecessor, whose work has been largely concerned with the systematic and philosophical side of Botany, has rightly expressed the general desire for a more cordial understanding between botany and its economic applications. 'It is certain,' he said, 'that our outlook must be widely different after the war, and the changed environment must find us ready to respond in the interest of our country and mankind.'

With your permission, and acting on a suggestion made by my Committee, I propose to travel a little outside the usual scope of previous addresses and review the many efforts that have been made, and are still being made, to promote the interests not only of the home land but of the Empire as a whole. My own activities have been more or less intimately connected with the Tropics. Their productions are daily in increasing demand, and are becoming more and more necessary to the inhabitants of temperate countries. Before the war it was estimated there were about three million square miles of British territory within the tropical zone. A portion of this area, including India, was already producing commodities of the estimated value of 230 million sterling.

It is, therefore, in the national interest to keep closely in touch with the conditions and prospects of our tropical possessions, in order that we may render them still more capable of supplying the raw material so necessary to the maintenance of our commercial prosperity.

In recent times one of the most important steps taken in this connection was the establishment, on the recommendation of a Royal Commission, appointed by Mr. Joseph Chamberlain, of an Imperial Department of Agriculture in the West Indies. The provision for the upkeep of the Department, approved by Parliament, was at the rate of £17,400 per annum. From the first special efforts were made to bring the resources of science to bear on all matters relating to the welfare of the Colonies concerned. The laboratories and the headquarters of the Department were established at Barbados, together with a staff of University men with special qualifications for research. The latter carried on their work in co-operation with officers of a like standing at British Guiana, Trinidad, and Jamaica.

When fully organised the Department made grants for teaching science at

colleges and secondary schools, and for the maintenance of agricultural schools, botanic gardens, and experiment stations. Special attention was devoted to research work in raising new varieties of sugar-canes and other plants, in the investigation of diseases affecting crops, and the general amelioration of the conditions under which they were grown. Further, by means of an efficient staff of travelling agricultural instructors and an abundant supply of literature the Department was brought into intimate touch with all classes of the community. At the end of ten years of strenuous effort it was noticeable, owing to the expansion and improvement of old industries and the introduction of new industries, the general conditions in the West Indies were greatly improved. This may be illustrated by the fact that the public revenue of the Colonies had increased from £2,546,724 in 1894 to £3,914,434 in 1911, while the total trade during the same period had increased from £16,270,474 to £26,949,086. There was thus an increase of 65 per cent. in the total revenue and of 60·5 per cent. in the total trade. In reviewing the situation in the West Indies, as the result of the activities of the Imperial Department of Agriculture, and those associated with it, the late Prime Minister said 'the work of the Department was universally and gratefully acknowledged by the planters to be largely responsible for the improved state of affairs in all branches of agriculture, and he believed—and he spoke with some experience—it would be difficult to find a case in which any analogous experiment made by the Home Government had attained such speedy and satisfactory results.'

A gratifying proof of the value of the work of the Imperial Department of Agriculture in the West Indies was the formation of several departments on similar lines, first at Pusa in India in 1902, and subsequently in all the tropical Colonies in the New and Old World. Further, twenty competent officers trained in the West Indies are now in charge of Departments of Agriculture in Ceylon, Mauritius, Federated Malay States, Fiji, and on the staffs of the Imperial Department of Agriculture in India and the several Colonies in East and West Africa. Another interesting feature of West Indian progress was the wider appreciation of improved methods of cultivation and the value of science by members of the planting community. For instance, in 1898 the aggregate amount voted by the local legislatures for staffs, laboratories, and botanic and experiment stations was at the rate of 14,000*l.* per annum. Apart from the funds of the Imperial Department of Agriculture, it is probable that, directly or indirectly, the total amount contributed locally for scientific services is now not less than 60,000*l.* per annum. It is also to be noted that during approximately the same period the number of scientific and technical officers had increased from 67 to 142. This, however, is not confined to the West Indies, for in a list, published annually at Kew, the number of scientific officers attached to botanical establishments in various parts of the Empire had increased from 122 in 1892 to 332 in 1918.

There can be no doubt that not only in the West Indies but in all parts of the Empire 'enlightenment as to the objects, methods, and conditions of scientific research is proceeding at a rapid rate.' A review of the circumstances relating to all the Overseas Dominions would be a task entirely beyond my province. Perhaps the most interesting feature of the progress made is in connection with the application of the laws of heredity to the improvement of such highly important crops as sugar, wheat, and cotton. The problems associated with these involve both scientific and economic considerations. As regards the scientific side, it is fortunate that with the beginning of the twentieth century came the rediscovery of Mendel's facts and the stimulating energy of the genetic school which has brought us an entirely new point of view in regard to the improvement of field crops.

Great importance is attached to the improvement of the sugar-cane, as the prosperity of many of our possessions depends upon it. Further, the requirements of this country approach something like two million tons per annum. The sugar-cane, although its origin is unknown, has been cultivated in tropical and sub-tropical countries from remote ages. Up to a recent date its propagation was purely vegetative, as it was supposed to have lost the power of producing mature seed. Occasionally by bud variation a new cane was obtained possessing special merit. For instance, at Barbados in 1903 a 'sport' cane cultivated under normal conditions yielded at the rate of 8,070 pounds of sugar per

acre as compared with 6,228 pounds yielded by the original cane. In Java, where the white Cheribon was practically the only kind grown, a red cane suddenly appeared. This was carefully multiplied by cuttings until a large area was planted, with the result that a greater tonnage of canes was raised per acre and the juice was richer.

Sugar-cane seedlings were observed at Barbados in 1858, but it was only in 1888 that Bovell and Harrison were in a position to utilise the discovery and obtain thousands of self-sown seedlings for experiment purposes. Similar seedlings were also available in Java about the same time. As about this period the standard canes in sugar-growing countries were showing signs of being severely attacked by disease the discovery of seedlings was a fortunate circumstance. In fact, in some cases it may be regarded as having probably saved the industry. A careful examination of the floral characters of the best varieties of sugar-canes disclosed the fact that in some cases the ovary was normal while the stamens were infertile. Advantage was taken of this circumstance to secure cross fertilisation by planting selected canes of each type in alternate rows. By this and other means, skilfully devised, several varieties of sugar canes of great merit were raised.

The possibility of breeding sugar-canes by cross fertilisation under control on Mendelian lines has so far not proved practicable. Partly on account of the enormous number of florets in the panicles and their microscopic character, but chiefly owing to the difficulty of manipulation in the field. Lewton Brain and Stockdale made careful experiments in 1903 and 1905, but the results in both cases were disappointing. In spite of this a large number of seedling canes have been raised in cases where the seed-bearing parent only was known. In others neither parent was known. The results, on the whole, have not been unsatisfactory. Seedling canes in many cases have taken the place of the older varieties, while larger returns per acre have been obtained. Further, owing to careful selection there has been a marked diminution in the losses from the attacks of insect and fungoid pests.

In British Guiana it is reported that in the crop of 1918 seedling canes occupied 83 per cent. of the total areas under canes. Similar results have been obtained at Barbados, where Bovell has continued since 1888 in raising canes of great merit. Also in the Leeward Islands, and more or less in Trinidad and Jamaica. The best of the West Indian seedlings have been widely distributed to other countries. The general policy adopted by Harrison in British Guiana as the result of over thirty years' experience in cane selection is briefly summarised as follows: 'We raise as many seedlings as we can from varieties of proved vegetative vigour, and select from those having both well-marked vegetative vigour and relatively high saccharine content.' He adds: 'The characteristics of seedling canes are not fixed, and in many instances characteristics which in the earlier years promised to make a cane of high quality, both in the factory and field, were the first to fail.' Harrison's experience suggests a special line of research, viz., to ascertain the cause of the increase in vegetative vigour and yield that follows a first cross, only to disappear in later stages.

In India there is probably a larger area under sugar-cane than in any other country. Its production of sugar is over two million tons. The larger proportion of this consists of a low-grade quality known as jaggery or *gur*. Palm-sugar is also produced to the extent of half-a-million tons. The sugar-producing areas in India consist of two main portions: A southern portion in Madras, Mysore, and Bombay wholly within the Tropics, and a northern portion outside the Tropics extending from Assam to the Punjab, a distance of one thousand miles. The difference in soil and atmospheric conditions has a marked influence on the character of the canes grown in the two regions. In Southern India the canes are stout and usually as productive in the irrigated areas as in other tropical countries; but in the North the canes are more slender, grow in thick clumps, and owing to the high percentage of fibre are much less productive in sugar.

Speaking generally, the sugar industry in India is not in a satisfactory condition. In spite of the enormous area under cultivation India is obliged to increase its considerable imports of sugar from Java and other countries. To obviate this urgent steps are being taken to improve the character of the canes and establish varieties adapted to local conditions and the circumstances of the sugar growers. The latter are almost entirely of the peasant class or rayats. At

first it was sought to introduce better varieties of canes from other countries. A sugar station was established for this purpose at Samalkola. It was soon evident that the luxuriant canes of the Tropics were not suited to the special conditions existing in Northern India. What was needed was a more hardy type of cane capable of holding its own under the field conditions and the resources of the cultivators. To obtain these they had to be produced in India. With this object in view a cane-breeding Research Station was established in 1910 at Coimbatore, with Barber, an experienced scientific man, in charge. The locality was regarded as favourable because canes were known to flower there comparatively freely. At first the improvement of local canes by selection and later by seedlings from parents of known vigour and high saccharine quality received attention.

In raising seedling canes the chief difficulty was the irregular flowering of the best canes. Barber arrived at the conclusion that until some control of the flowering is obtained work on Mendelian lines was not practicable. In spite of this a large number of selected seedlings are now being raised at the rate of 4,000 per annum. Some of these, lately distributed to the experiment stations in Northern India, have been reported upon as 'entirely satisfactory.'

Much more still remains to be done, but there is reasonable hope that a race of superior hybrid seedlings will be produced that will eventually displace the inferior local varieties hitherto cultivated. To ensure even moderate success in this direction it is recognised that the work of cane-breeding must never slacken, and further, that the means of distribution and the number of stations and capable workers must be increased.

In the considerable literature of sugar-cane breeding in India Barber has brought together a vast amount of information of singular interest and value. In the few years that have elapsed since he has been in charge of the Coimbatore Research Station he has laid the foundation of lines of inquiry that cannot fail to prove of great value in the permanent improvement of the sugar industry in India. It is a good augury as regards the future that the Government of India has lately formed an Imperial Sugar Bureau, whose duty it is to collect and collate the scattered results obtained in various directions and keep closely in touch with the sugar work done in India and in other sugar-producing countries.

In his Presidential address in 1898 Sir William Crookes stated that the prime factor in wheat production was a sufficient supply of nitrogen. As the supply was then showing signs of exhaustion he warned wheat growers of the peril awaiting them. Sir R. H. Rew has now shown that, thanks to the chemist, who came to the rescue, there is practically no limit to the resources of nitrogen. What he hoped for was that the future would see not only a larger acreage in this country under wheat but also a substantial increase in the average yield. During the great war the British people have realised under the stress of a fight for existence that the question of food supply is the most vital of all national interests. Both in this country and in India and in the Overseas Dominions great progress is being made in raising new varieties of wheat yielding large returns per acre and possessing excellent milling and baking qualities. In the pre-Mendelian days excellent work was done in wheat breeding by Saunders in Canada and Farrer in New South Wales. Their work proved of enormous benefit, as it not only provided varieties of superb quality, but also those that could be successfully grown in districts where wheat growing for various reasons was previously impossible. During recent years Biffen by his successful investigations on Mendelian lines at the Plant Breeding Institute at Cambridge has shown that the characteristics distinguishing the numerous wheats can be traced, and the building up of a fresh combination of these characters was possible on practical lines. As the losses caused by disease were so serious, sometimes running to millions of quarters annually, Biffen devoted special attention to the possibility of breeding rust-resisting varieties. He found that the power of resisting the attacks of yellow rust, for instance, was an inheritable character. By crossing 'Gurka,' a Russian disease-resisting wheat, with Square Head's Master, one of the most widely cultivated wheats in this country, Biffen eventually produced 'Little Joss,' which, after trials extending over a period of several years, is said to yield four bushels per acre more than any other variety. Further, it possesses distinct disease-resisting qualities.

Another of Biffen's new wheats is 'Yeoman.' This was raised in order to produce what are known as strong wheats. These are in great demand in this country, as they produce a flour which is much superior for baking purposes to the flour of English wheat. In pre-war days Canadian strong wheats commanded in the market 5*s*. more per quarter than the best English wheat. 'Yeoman' not only possesses the superior quality of Canadian wheat but combines with it the high-yielding character of certain English wheats.

A well authenticated report, supplemented with full details, of the value of 'Yeoman' as a field crop was lately published.[1] It was cultivated under normal conditions, but without artificial manure, on three fields on a large farm near Wye, Kent. The cropped area was a little over twenty-seven acres. The total yield was 2,072 bushels, or an average of about seventy-seven bushels per acre. One field, previously under beet, comprising three acres two rods and eight poles, yielded 340 bushels, or an average of eighty-six bushels per acre. These results may be compared with thirty-two bushels, the average yield of wheat in this country.

Further, in another variety known as 'Fenman,' Biffen has produced a wheat with a short, stiff straw for the Fen country. This is able to withstand the usual tendency of the ordinary sorts to grow tall and be beaten down and injured in rainy seasons. A most desirable improvement in wheat growing in this country is to obtain a spring wheat combining early maturity with a yield approaching that of winter wheat. There is likely to be a difficulty in securing these most desirable results, but what Biffen has already achieved in dealing with qualitative and quantitative characters offers fair promise of success. The establishment of a National Institute of Agricultural Botany for the further development of plant breeding and the distribution of pure seed may be regarded as essential to the welfare and safety of the nation.

Wheat growing is a very important industry in India. It was estimated in 1906-7 that twenty-nine million acres were under cultivation in wheat with a yield of nearly nine million tons. Of this 90 per cent. was consumed in India. A botanical survey of the Indian wheats was undertaken by the Economic Botanists at the Imperial Research Institute at Pusa in 1910. In the following years by the application of modern methods of selection and hybridisation high-grain qualities were successfully combined with high-yielding power, rust resistance, and stiff straw, so that wheats were produced which gave upwards of forty-one bushels per acre.

Among the best of the new varieties are Pusa 4 and Pusa 12. Owing to an organised system of distribution of seed it is estimated that the area under Pusa 12 during the last wheat season (1918-19) was about 400,000 acres. The area under Pusa 4 was about 100,000 acres. The increased yield of 25 per cent. over the varieties formerly grown in India as well as one shilling per quarter more on the market, owing to the improved quality of the grain, are factors of great value as regards the future of wheat growing in India. Pusa 4 and 12 are said to possess the added advantage of being able to mature with less water than the ordinary Indian wheats.

The important work carried on at Pusa by Howard and his accomplished wife has followed closely on the methods found so successful at Cambridge. It is interesting to note that in obtaining new kinds by hybridisation between Indian wheats and rust-resisting forms in Northern Europe a difficulty in regard to flowering at different periods was overcome by sending the Indian parents to Cambridge for spring sowing and by carrying out the actual crossing with Biffen's new hybrids in England. From the crosses thus obtained Howard reports that a wide range of wheats has been evolved likely to prove superior to Pusa 4 and Pusa 12.

The admirable work done by Biffen at Cambridge and the Howards in India clearly demonstrates the value of thorough acquaintance with pure Botany as a qualification for grappling with questions of economic importance.

In reviewing the gain to Indian wheat growers the Director of the Agricultural Research Institute has recently stated that in view of the favour with which the new wheats have been received and the cordial co-operation of provincial

[1] *Journ. Bd. Agric.* xxv., 1161.

organisations 'it is a modest estimate to assume that in the course of a very few years the area under Pusa wheats will reach five million acres. This means an increase in the near future in the value of the agricultural produce of India, in one crop only, of 75 lakhs of rupees or five million sterling.' Another crop that has received attention is indigo. In regard to this a new method of growing the seed has been worked out, and the cause of the destructive wilt disease has been traced to the destruction of the fine roots and nodules during the monsoon rains. The remedy in this case is the selection of surface-rooted plants which are now in course being generally grown.

Considerable progress has also been made with rice, the chief cereal food of the people of India. Of this eighty million acres are cultivated. A variety known as 'Indrasail' is being rapidly propagated. The yields of this in 1915-16 were 30 per cent. over the ordinary kinds. In 1918 two hundred tons of pure seed were distributed in Bengal, which contains one of the great rice-producing tracts of the world.

Some wheat breeding has been carried on in the Argentine by Backhouse, formerly attached to the John Innes Institution. The conditions in that great country extending from the Straits of Magellan to the tropic of Capricorn are exceptional in the diversity of soil and climate. The wheat cultivated in such widely scattered areas requires to be carefully adapted to local conditions, and the work must take a long time. Confining attention to the dry districts of the north, Backhouse found an interesting variety in general cultivation known as Barletta, which, though mixed and heterogenous, was uniform in possessing a non-shelling character. Further, during periods of drought it acquired the habit of abandoning tillering and producing only one or two rows of ears. Its chief defect was its liability to be attacked by *Puccinia triticum* (not *P. glumarum*). In some years 20 per cent. of the crop was lost owing to this rust. It was ascertained that European varieties immune to *P. glumarum* were susceptible to the Argentine rust.

A Chinese variety taken out by Backhouse was found to be immune to *P. triticum*. From this eventually was built up a form that combined some of the best qualities of the Barletta with the immunity of the Chinese. Backhouse has since endeavoured to increase the size of the grain, which is small in Barletta, and improve the general yield. The adaptability of the Barletta, as a non-sheller, to the conditions in the Argentine is due to the fact that the harvesting is done there by an Australian machine which cuts off the ears and threshes them at the same time. A non-shelling, or what is also known as a tight-glumed, wheat is therefore essential.

As in wheat, so in cotton, this country is almost entirely dependent on foreign supplies. The uneasiness caused by the excessive dependence of the great Lancashire cotton industry, with exports of the annual value of over a hundred million sterling, on supplies from abroad, and the occasional shortage, have led to general action being taken to encourage the more extensive growth of cotton within the Empire. Next to the United States, which in some years have supplied seven-tenths of our imports, India comes second, but the East Indian cotton is not well suited to the requirements of the English spinner. Egypt, as the third producing country, supplies cotton of great strength and fineness.

The most valuable of all cottons is that known as 'Sea Island' cotton owing to its introduction and successful cultivation on the coastal areas in South Carolina, Georgie, and Florida. With regard to this, it is interesting to learn that in recent years Sea Island cotton has been introduced back again to the West Indies, which was probably its original home.

This was effected by the Imperial Department of Agriculture in the West Indies in 1902, when a pure strain of seed raised from plants immune to wilt disease was obtained in quantity from James Island. This insured that the industry from the first was placed on a firm basis, and with the hearty co-operation of the planters an important West Indian cotton industry was successfully established. For some years the West Indian cotton has obtained a higher price than the corresponding grades of cotton from the Sea Islands themselves. The fine spinners in Lancashire are now practically independent for their supplies of this cotton from the United States. Further, it is not improbable owing to the serious attacks of the Mexican boll weevil on cotton plants in South Carolina and Georgia the West Indies may become the only source of supply of

fine Sea Island cotton. To enable the cotton industry to be established in the West Indies it was necessary from the first to ascertain the best type of cotton to grow in each Island, how to plant and cultivate it, how to protect it from insect and fungus trouble, and how to maintain or improve the quality and quantity of the lint produced. The results so far obtained may be realised from the fact that the value of the exports of Sea Island cotton from the West Indies in recent years has reached a total of two million sterling. The general conditions in the West Indian islands owing to their small size and comparative isolation should enable them to maintain a high purity of cotton. In Egypt and other cotton-growing countries with continuous areas contamination by natural crossing leads to rapid deterioration of pure strains so that a system of continued seed renewal is necessary. Harland, whose services in the West Indies have been provided by a grant from the Imperial Department of Scientific and Industrial Research, has in hand important investigations with the view of placing the work of cotton selection and breeding on scientific lines.

He has shown that the yield of lint per acre depends on a number of factors of a morphological and physiological character. In a general way it may be said that the yield is dependent on the climatic conditions, so an effort is being made to produce varieties which will interact with the environment conditions to the best advantage. Although Harland's work so far is of a preliminary character, he is able to suggest the conclusion that following certain lines of selection and breeding, and bearing in mind the relative importance of lint index and lint percentage, it is possible to isolate a strain of Sea Island cotton with a weight of lint per boll 31 per cent. greater than that of the ordinary sorts in cultivation.

Considerable losses occur in some seasons from the attacks of insect and fungous pests. In some instance the Internal Boll disease is very destructive. This is due to the puncture of the young bolls by cotton stainers (Dysdercus) and green bug (Nezara), and the infection of the punctured locks or bolls by certain specific fungi which cause either total loss or the staining of the lint according to the amount and time of infection.

The green bug is naturaly controlled by egg parasites, but the cotton stainers are subject to little or no control. In St. Vincent highly successful results have followed the systematic cutting out, over the whole island, of two species of trees (Sea-side Mahoe and the Silk cotton) on the fruits of which the cotton stainers breed during the period between the cotton crops. The investigation of the Internal Boll disease has entailed wide research, and illustrates the great complexity of problems in tropical plant pathology, as also the need of correlation and the combination of knowledge obtained by simultaneous action from several points of view.

A point of scientific interest is the inheritance of immunity in cotton from the attacks of the Leaf-blister mite (*Eriophyes gossypii*). Harland believes he has obtained this by crossing an immune type of native cotton with a susceptible type of Southern Cross Upland cotton. In the F/3 generation all the plants breed true to immunity.[2] This is important from an economic point of view, for it may lead to the possibility of the production of an immune strain of Sea Island cotton which has hitherto been very badly attacked by the Leaf-blister mite. Another instance of immunity from insect attack is a hybrid of maize (*Zea indentata*) and *Teosinte mexicana*, which is claimed to be totally immune to the attacks of certain aphids.[3]

As already mentioned, India is the second largest producer of cotton. In 1906-7 it was estimated that there were about 20 million acres under cotton, with a production of nearly 5 million bales. It is unfortunate that the quality of East Indian cotton is not high in spite of the considerable efforts made in recent years to improve it.

Cambodia cotton for a time proved successful in Southern India, and has lately been introduced to Madras, but chief attention is directed to the improvement by systematic selection of pure strains adapted to local conditions. In Madras in 1917-18 there were 250,000 acres under new varieties of cotton, yielding increased returns to the rayats of the value of £416,000 per annum. A variety known as 'roseum' was planted in the Central Provinces in 1916-17 on

[2] *West Ind. Bull.* xvii., 162.
[3] *Rev. App. Entom.* Ser. A., vi., 29.

700,000 acres, with the result that the profits to the growers reached a value of nearly one million sterling.

Leake's research work in the United Provinces, carried on for many years, is regarded as probably the most complete yet attempted with cotton in India. A variety known as K.22 has been widely distributed, and the produce in 1916 sold at 31 rupees per maund when local cotton was 25 rupees. Further, the ginning percentage has been raised from 33 to about 40, while the lint is of superior quality.

Leake has also been successful in raising an early flowering form of cotton on Mendelian lines. The new form differed from ordinary cotton cultivated in the United Provinces in that it assumed a sympodial instead of a monopodial habit. It not only yielded cotton of high quality, but it was found by its early flowering habit to suit the special conditions of the United Provinces.

As Egyptian cotton comes next to Sea Island cotton in quality it may be useful to refer to what has been done, or attempted to be done, on scientific lines to safeguard the industry. Its importance may be gathered from the fact that the area under cultivation is between a million and a-half and two million acres. Balls has fully reviewed the scientific and other problems that had to be solved in placing the industry on a satisfactory footing.

In the first place, as in all cotton areas, it had to be realised that it was necessary to produce varieties on pure lines. An attempt to produce crosses between American Upland and Egyptian cotton had to be abandoned. It was then resolved to select strains of individual Egyptian sorts and by the study of heredity on Mendelian lines to raise new varieties of pure strain. It was hoped by these means and by organising an effective system of seed distribution, year by year, to maintain the general purity of the crop. The chief difficulty met with was in respect of the relatively small size of the unit areas and the liability of the pure-strain plants being contaminated by pollen carried by wind or by bees from the neighbouring areas. According to Balls, the high-water mark of Egyptian cotton growing was from 1895 to 1899. Since that time, although the actual area under cotton had been increased by 600,000 acres, the benefit measured in terms of cotton alone was small. It is probable that the attacks of the pink boll worm and other pests may have affected the results, but Balls and his colleagues came to the conclusion 'that the falling off in yield was due to a rise in the level of the sub-soil water, or water table of the country brought about by the extension of the irrigation system during the past decade.' The roots of the cotton plant were thus adversely affected at a critical period of growth. This recalls what Howard discovered, that one of the causes of the wilt disease in indigo in India was the destruction of the fine roots and nodules during heavy monsoon rains. This shows, as suggested by Balls, how small was our real knowledge of the root functions of plants, and in the experiments carried on by him and his colleagues in Egypt they were 'semi-consciously building up a general scientific knowledge of root-function worked out on the cotton plant as our material.'

Balls, while carrying out numerous investigations bearing on the production of pure strains of Egyptian cotton, devised a method of recording crop-development by means of illustrative graphs likely to be adopted not only for cotton but other crops. Incidentally, he proved that the close-planting method on ridges adopted by the native cultivators in Egypt was more advantageous than the wider planting adopted in the United States and other countries. It is a sign of the times that a British Cotton Industry Research Association has recently been formed at Manchester to promote a wide scheme of research in connection with the production of cotton and its utilisation in industry. It will employ a staff of scientific and skilled workers, and maintain scholarships, and eventually a Cotton Research Institute is in contemplation. It also proposes to establish research stations in the cotton-growing portions of the Empire for the investigation of the growth of cotton and the careful and complete study of the scientific problems that may arise.

Probably the most remarkable instance on record of the successful combination of science and enterprise in the Tropics is the establishment of a cacao-growing industry in the Colony of the Gold Coast, West Africa. Thirty years ago no cacao of any kind was produced on the Coast. Owing, however, to the foresight of the then Governor (Sir William Brandford Griffith), who sought

the powerful aid of Kew, cacao growing was started in a small way among the negro peasantry, with eventually extraordinary results. After selecting the locality for the experiments, seeds and plants were obtained through Kew, and a trained man was placed in charge.[4] The first exports in 1891 amounted to a value of £4 only. So rapid was the development of the industry that ten years later the exports reached a value of £43,000. By this time both the people and the Government had begun to realise the possibilities of the situation, and systematic steps were taken to organise under scientific control a staff of travelling agricultural instructors to advise and assist the cultivators in dealing with fungoid and insect pests and improve the quality of the produce. In 1911 the exports had increased nearly fourfold, and reached a total value of £1,613,000, while in 1916, what may possibly be regarded as the maximum exports, were of the value of £3,847,720.

It should be borne in mind that this Gold Coast cacao industry, now one of the largest in the world, has been called into being and developed entirely by the agency of unskilled negro labour, and on small plots from one to five or ten acres in extent. The controlling factors were, first, the selection of suitable land for cacao growing; next, the selection and supply of seeds and plants of varieties adapted to local conditions; and, lastly, the advice and tactful assistance of trained Europeans backed by the resources of science.

Coming nearer home, Henry, well known from his association with Elwes in the production of 'The Trees of Great Britain and Ireland,' by historical research and experiment has established the fact that many fast-growing trees in cultivation as the Lucombe Oak, Common Lime, Cricket-Bat Willow, Black Italian Poplar, Huntingdon Elm, etc., are hybrids. It was of high scientific importance to discover the origin of these valuable trees. Further, by artificial pollination Henry has succeeded in raising new hybrids which display the extraordinary vigour characteristic of the first generation cross. Perhaps the most notable, so far, is a new hybrid Poplar (*Populus generosa*), which makes the strongest shoots of all Poplars.

The astonishing vigour of hybrid trees is well illustrated in the case of the Cricket-Bat Willow, a natural cross between *Salix fragilis* and *S. alba*. 'This oftens attains in fourteen or fifteen years, from the planting of sets, fifty to sixty feet in height, with three and a-half to four feet in girth—a size suitable for cleaving into bats.' It is claimed in the case of many hybrid trees 'it is possible to produce much greater bulk of timber in a given time.' The common belief that quickly-grown timbers are of inferior quality is said not to hold good in respect of any quality in Ash, Oak, and Walnut. In fact, according to Dawson, 'with oak, ash, and walnut the quicker their growth the better their quality in every way. They are more durable, more elastic, and less difficult to work.[5] It is further claimed that by hybridising it may be possible to produce disease-resisting varieties and varieties carrying with them other desirable characteristics.

Difficulties are met with in hybridising trees in this country owing to the variable climate and the absence of pollen and desirable sorts. To obviate these and provide adequately for the work it should be undertaken on organised lines, as in wheat breeding.

Henry has recently made an elaborate investigation into the history of the London Plane (*Platanus acerifolia*).[6] He has established the fact that this tree, never seen anywhere in the wild state, is intermediate in character between an American and a European species. He claims it has all the peculiarities of a first cross. As usual in hybrids of the first generation, its seeds when sown produce a mixed and varied crop of seedlings, in which are variously combined the characters of the two parents.

Henry's researches show that the London plane probably originated in the Oxford Botanic Garden about the year 1670, when both the occidental and oriental planes were established there. The finest and probably the oldest London plane in Europe is growing in the Palace Garden at Ely. It was planted by Bishop Gunning between 1674 and 1684. The vigour of the London plane

[4] *Kew Bull.* 1891, 169; 1895, 11.
[5] *Science and the Nation*, 138.
[6] *Proc. Roy. Irish Acady.* XXXV. B.2.10.

is remarkable. It is extensively used for planting in London and other towns in this country, and also in Europe and North America, 'as it has been found to surpass all other trees in its powers of resistance to drought, smoke, and other unfavourable conditions of soil and atmosphere.'

In the Tropics breeding experiments in the case of india-rubber trees are likely to prove of great value. In the meantime, selection of seed from the best trees is being carefully carried out in the hope of increasing the general yield of the plantations. In Java the proportion of alkaloids in the bark of introduced Cinchona trees (yielding quinine) have nearly doubled by careful selection on these lines. In the case of rubber trees, which are known to possess marked individuality in regard to the amount of latex which can be drawn from them, it is suggested that seed for planting should be taken only from trees selected for their high-yielding capacity. In fact, the selection of seed bearers may play an important part in the future development and permanence of the rubber industry. Where good seed is not readily available Lock has suggested that the best trees might be raised from cuttings.

Plant-breeding experiments with india-rubber trees have already been attempted, but they are not likely to be of much value if they are confined to empirical and haphazard lines. It is suggested that they should be carried on at well-staffed and well-equipped stations devoted to breeding and kindred problems. Such stations should be established in each of the main rubber-growing regions. Work of this kind must be lengthy and complex, but it is absolutely essential to ensure the safety of an industry which is estimated to be of the annual value in the Middle East of about fifty millions sterling. The Agricultural Department in Ceylon, which is fully alive to the fundamental importance of selection and breeding india-rubber trees, has already taken some action in the matter. For instance, at the Heneratgoda Gardens there are fifty *Hevea* trees whose individual latex-yield has been recorded for every tapping since June 1908. One tree marked No. 2 has yielded an amount of rubber far in excess of any other tree. In 1912 seeds and stumps taken from this tree have been established on a plot of three acres at the Experiment Station at Peradeniya. When the trees are fit for tapping and the good yielders are determined the others will be cut out and the remainder reserved for seed purposes.

Another investigation in hand is to determine whether the latex-yielding quality of *Hevea* trees can be associated with any definite botanical characters and to what extent such characters are transmitable. Twenty trees of the same age growing in a four-acre block have been selected for differences in leaf and bark characters. These are all tapped on the same system, and the yield of rubber from each tree is recorded separately for each tapping.[7]

The value of these and other experiments of a like nature may be realised when, according to Varnet, quoted by Johnson, the yield of rubber from different trees of *Hevea* growing under similar conditions in the same plantation may vary as regards volume of latex from 4 to 48, and in percentage of weight of dry rubber from 1.286 to 14.164.[8]

Bateson a few years ago expressed the opinion that nowhere is the need for wide views of our problems more evident than in the study of plant diseases. Hitherto, he said, 'this side of agriculture and horticulture, though full of possibilities, for the introduction of scientific methods, has been examined only in the crudest and most empirical fashion.'[9] Since then some advance has been made in the morbid physiology of plants, but such work to be carried to a successful and practical issue demands careful experiments carried on continuously by specialists for many years.

Keeble suggests that "the professional mycologist is accustomed to confine his attention too exclusively to the active agent of the disease,' while, on the other hand, 'the professional cultivator gives habitually great weight to the possibility of preserving plants from disease by improving his methods of cultivation. Both are right, yet neither is wholly wise, and there is much room for a race of mycologists who not only discover how to cure plants but know

[7] *Kew Bull.* 1917, 118.
[8] *Jour d'Agric. Tropicale*, 1907.
[9] Address, Section M., 1911.

how to cultivate them.'[10] As we have already seen, Biffen and others have shown that under certain conditions the quality inherent in some varieties to resist disease may be utilised to great advantage. The national importance of such work is impressed upon us by the enormous losses sustained every year by rust in wheat, mould in hops, and the widespread disease of potatoes. One of the most striking instances in recent times was the destruction of the valuable coffee plantations in Ceylon. The industry, an exceptionally valuable one, was wiped out in a comparatively few years by the coffee-leaf disease (*Hemileia vastatrix*). In the light of our present knowledge it is not improbable that this disease may have been checked by seed selection or raising an immune race of plants. Or, more probably, as suggested by Armstrong, by regulating the use of essentially nitrogenous manures, which are known in some cases to intensify the attacks of fungoid pests and substituting the use of phosphates.

In the Malay States the life history of some of the more prominent diseases of rubber trees has received close attention. *Fomes lignosus*, a root fungus, is local in character, and as its effects quickly appear there is time to take remedial measures before the neighbouring trees are affected. *Ustulina zonata*, causing collar-rot, on the other hand, is slow in action, and therefore all the more dangerous. A third rubber disease, *Fomes pseudo-ferreus*, spreads entirely by the contact of the roots with diseased jungle stumps, or roots of other diseased rubber trees. As remedial measures are impossible in this instance a clean-clearing policy is being vigorously advocated, and under scientific advice this may become the rule on all young rubber estates in the East. In this country Salmon, who is undertaking a detailed study of the hop mildew (*Sphærotheca humili*), has obtained seedlings which he states 'have retained immunity after four years' trial in a hop garden under normal conditions of cultivation and manuring.' As the depredation of mildew, commonly known as mould, causes great loss to hop growers, the research work carried on by Salmon is watched with great interest. Progress is necessarily slow, but a hop immune to mould would be a valuable acquisition in hop-growing districts. In the successful treatment of the diseases of plants the field of work in the Empire is realised as practically without limit; but it is one in which advance must be made by the development of pure science, and by men with a broad outlook and fully in touch with the practical as well as the scientific side.

As illustrating the occurrence of an incidental result arising from a purely scientific investigation, mention may be made of the discovery of a remarkably tall strain of flax at the John Innes Institution. This, if capable of being established on pure lines, may prove of economic value. It is a hopeful sign that the appreciation of the work done at this institution, under the stimulating energy of Bateson, is increasing day by day. The broad-minded interpretation that has been placed on the generous bequest made by Mr. Innes and the recognition of the fact that an accurate knowledge of heredity must form the basis of the bulk of the new work in horticultural breeding are full of promise. We have, further, the assurance that recognition will be given to the principle that if progress is to be made theory and practice must be closely interwoven. Amongst other important investigations undertaken at the John Innes Institution, Miss Ida Sutton has recently published a Report on Self-sterility in such fruit-trees as plums, cherries, and apples. It has been recognised that failure in fruit crops is not infrequently due to self-sterility. Two main questions were dealt with, (1) whether self-sterility is a simple Mendelian recessive character, and (2) whether self-steriles are fertile with the pollen of any other variety. So far, with regard to (1), the results show there is nothing which negatives the view that the property of self-sterility may be recessive, and in regard to (2) what East has called 'cross-incompatibility' is not confirmed by Miss Sutton's researches. The general conclusions arrived at by Miss Sutton are: (*a*) that many important commercial varieties of fruit trees set little or nothing unless cross-pollinated; (*b*) that for the pollination of these self-sterile kinds pollinisers must be planted; (*c*) that provided a variety produces plenty of pollen and flowers simultaneously with the variety which is intended to pollinate, any variety, at least of plums and apples, will probably serve for this purpose,

[10] *Science and the Nation*, 118.

apart from the special case of the Coe varieties of plums and their presumable co-derivative, Jefferson. We may mention the great success which is attending the establishment of a school of technical education and research by the Royal Horticultural Society at Wisley. This is maintained by liberal funds, and by means of its well equipped laboratories and extensive trial grounds it offers unique facilities for solving problems of great value as affecting the future of British horticulture. In sympathy with the work at Wisley private firms are also setting up laboratories of their own and employing men of high standing so that a just balance will be maintained between science and practice. By such means research will be stimulated and encouragement given to individual initiative which is recognised as fundamentally important in the advancement of science.

In schemes of intensive cultivation so ably advocated in reference to food production, it is well to bear in mind that it may be possible in some instances to go beyond what is necessary to achieve the object in view. Russel is of opinion that 'the more intensive the cropping the greater the opportunity for the various pests to live. . . . Further, most pests have their parasites, and wholesale sterilisation may help the pest by destroying the parasites. Imms has recently noted two cases where this is said to have happened.[11] I may add a third instance of this character in the case of the Moth Borer attacking sugar-canes in the West Indies. For probably something like two hundred years the moth borer had been regarded as the most destructive enemy of the sugar-cane. Its life history was unknown until Lefroy, then attached to the Imperial Department of Agriculture, discovered the eggs which were deposited in a greenish cluster on the back of the leaves of the sugar-cane. The egg clusters were so inconspicuous that they had entirely escaped notice. The first steps were to employ boys to cut off portions of the leaves with the eggs and burn them. It was afterwards discovered that many of the eggs were parasitised, and the planters were thus unknowingly destroying the parasite, and practically increasing rather than diminishing the attacks of the moth borer. On the further advice of Lefroy the leaves with the egg clusters were not burned but spread out in the shade to enable the parasites to hatch out, with the result that in the later stages of the crop nearly all the moth-borer eggs were parasitised, and the loss in canes in that and the succeeding crop was largely reduced by natural means.

The progress made in the elucidation of problems in tropical plant pathology shows not only the necessity for well trained and experienced mycologists and entomologists, but also for the correlation and combination of knowledge gained in their several lines of study. It is suggested that research work should be organised on the broadest possible lines, and combine the biological services of the whole Empire. We have a first step in this direction in the Imperial Bureau of Entomology, with its headquarters at the British Museum. Those acquainted with the efficient work done by this Bureau and the excellent publications issued by it will very heartily welcome the establishment of the proposed Imperial Bureau of Mycology, to carry on its work on similar lines.

In this brief review I have endeavoured, however imperfectly, to place on record some of the activities that have taken place in the domain of Botany in recent years. It has only been possible to select a few of the most striking incidents where progress has been made. This has been done in the hope of arousing wider interest in work of prime importance as affecting the interests of the home country and the Empire. Botany in its widest aspects affects so largely the welfare of the human race it is impossible to slacken our efforts. Advance has necessarily been slow, but the creative impulse of science cannot fail to bring in a large harvest of results. This may be possible by encouraging individual efforts, by organising active co-operation and in associating with us men who are practically grappling with difficulties that seem almost impossible to solve. I have attempted to show in what vast fields of enterprise botanical science has already rendered signal service. As regards the future, if we enlist the best intellects imbued with the true spirit of progressive research, we shall ensure a continuance of discoveries that have proved so effectual. We must also

[11] Address, 1916, p. 17.

call to our assistance some of that wonderful energy developed during the war and divert it to the great work before us.

Certainly one of the outstanding features that emerges from a record of botanical research during the last decade or two is the prominent position occupied by plant-breeding on Mendelian lines. In proof of this we have the numerous well-equipped plant-breeding institutes established and maintained by Government and private funds. Plant-breeding is now in the forefront in relation to the improvement of crops, and the value of it is officially acknowledged as 'a vital element in the national policy.' According to the Secretary of the Board of Agriculture, what we want 'are new races of plants adapted to intensive cultivation,' and, he adds, 'it is my deliberate opinion that an increase in the production of our land is much more easily attainable in that direction than in any other.'

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ADDRESS

TO THE

EDUCATIONAL SCIENCE SECTION

BY

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PRESIDENT OF THE SECTION.

Educational Ideals and the Ancient Universities.

A PRESIDENTIAL ADDRESS before the Educational Section of the British Association is an undertaking that might fairly daunt the bravest of those who are really acquainted with its difficulties; the vast range and variety of the problems of education; the enormous amount of effort that is already expended upon them; the torrents of advice and criticism that are offered by those who are familiar with the details of the various curricula, who know how things ought to be done; if I had had time and capacity to become acquainted with all these things I suppose I must have avoided the duty of making an address. It is, perhaps, the detachment of my present position from any responsibility for details which gives me the courage to recall experiences, now twenty years old, acquired during a lengthy service in various capacities at Cambridge, and matured by twenty years of the consciousness of the dire need of educational discipline and training for those whose business it is to use science in the service of the State.

With a certain amount of assurance I can even be glad that I am not in touch with the educational controversies of the hour, and confidently trust that my deficiencies will be made good by the contributions, of those who know, to the discussions which will take place in the Section, but the difficulty that I cannot get over just now is that, from the unavoidable circumstances of the present time, a presidential address is a 'back number' before it is delivered, for the simple reason that, according to tradition, it must be printed in advance. In this particular year there is an almost immeasurable gulf of experience between the time of my appointment in 1917 and the delivery of this address; the President himself is in many ways a different person from him who undertook the duty of addressing you two years and a half ago.

At that time I had been a good deal moved by the wearying controversy about the relative merits of classics and science in education, because the physical sciences as taught were such a doleful misrepresentation of the spirit of inquiry about the Universe which has moved men in all ages and is as clamant to-day as ever. The mysteries of the firmament, the midnight sky, the storm and calm, the earthquake and the thunder, the sunshine, the rainbow and the halo, the intolerable heat and the pitiless cold, the mariner's compass, the aurora and the mirage are still as wonderful as ever to the wayfarer and the seafarer, and even the dweller in towns wants to know more about them. Yet our educational system, as I knew it, passed all these subjects by and offered instead the determination of the specific heat of copper, with other things that the specific heat of copper stands for. The same, I believe, is true for many of the most interesting subjects of scholarship in

ancient and modern civilisations, learning and languages. And if an inquirer, young or old, should ask whether, if he went there, the great Universities could tell him all about the things of wonder or of beauty that he is conscious of, or about the reminiscences of past generations that he finds around him as he travels through life, he could only be told that in consequence of the perverse malignity of external circumstances they had no money to devote to his enlightenment. The capacity would be there in abundance but not the means. In three years they would put him in a position to pursue intelligently for himself if he pleased any of the subjects in which his interest had been excited but the facilities for education would extend only to the point where his interest began.

So I wrote a little pamphlet on the 'Lack of Science in Education with Some Hints of What Might Be,' and when I was invited to occupy this Chair I thought I might be of some service to Education if I pressed the subject further and endeavoured to show how, in spite of the goodwill of nearly everybody concerned, the peculiar constitution of our chief Universities was really standing in the way of the lofty ideal of higher education which must find expression if the education which we all want is really to come to pass in this country.

Circumstances have already vastly changed. Committees have sat upon the Teaching of Science and the Teaching of Modern Languages. A great Education Act has been passed and the poverty of the Universities has overstepped the limits of starvation, and a Commission of Inquiry is promised. So we are now on the high road to making presidential addresses matters of quite subordinate interest. Still, you may be interested to hear what I wrote, two years and a half ago, in explanation of the peculiar difficulties of our educational system, so here it is. It makes a good deal of play of a certain scene in 'The Merchant of Venice,' which I shall beg you to regard, for a few minutes only, as a satire upon the state of the Universities in the spacious times of Queen Elizabeth, after a period of magnificent activity on the part of founders and benefactors and after a succession of statutes for the Universities made by successive monarchs for the governance of those institutions which were then recognised as of the highest importance in the State. Such a period of reconstruction seems to have come again in our time, and the satire, if it be one, is in some important respects as true to-day as it was three centuries ago.

I was arrested by the curious sentiment 'If to do were as easy as to know what were good to do chapels had been churches and poor men's cottages princes' palaces.' I wondered whether Shakespeare intended this passage to convey to the subtle reader an idea of Portia's youth and inexperience, or perhaps to indicate that Portia was in fact intended to personify a liberal education. For other subjects of human activity her statement is palpably absurd. All the experience of the British race indicates to us that the acute divisions between people arise in discussions as to what were good to do; the actual doing is easy if the preliminary question 'what were good to do' is really decided. Can any one doubt that after our experience of the war? For the most part it is only ingenuous youth that finds it easy to know what were good to do, and perhaps there is also a note of the ingenuousness and inexperience of youth in the sweeping desire for the conversion of chapels into churches and poor men's cottages into princes' palaces.

But if it were education that Shakespeare was thinking about, chapels and churches, poor men's cottages and princes' palaces are not inappropriate in that connection; the sentiment stimulates the imagination. Certainly in education to know what were good to do does seem in practice to be infinitely easier than to do.

From time to time the newspapers are full of reports of conferences, meetings, congresses, and assemblies all fully assured that they know what were good to do. Men of science justly claim to be humanists and recognise the helpfulness of literary studies in their purpose; classicists recognise the need of a knowledge of science; everybody is agreed that many things ought to be done and yet very little happens: our scheme of education is still unsatisfying; why?

That is the question which I propose for your consideration. Why is it that all the pious opinions about education come to nothing or to so little?

First of all it must be noted that the resolutions and proposals are not addressed to anybody in particular. Presumably they are intended to form public opinion, but public opinion has no authoritative voice with those who are in charge of the higher educational institutions. The resolutions are sent out like wireless signals from a ship at sea. Any educational institution with a receiver tuned to the proper wave-length can take them in, but if the receiver is not tuned or the operator is inattentive nothing happens. Those who are in charge of the administration of our justice when they want to settle a disputed point do not hold a meeting and pass a resolution to be printed in the 'Law Times' or other forensic journals. They put a yellow paper in the post with blue lines drawn cross-wise over it, with somebody's name and address more or less legibly written thereon, and twopence in addition to the postage. The postman does the rest. The recipient is reminded of his duty by the laconic exhortation at the end 'Herein fail not.' There is no such simple process with educational procedure. We are accustomed to regard educational institutions as somehow in the aggregate responsible for what we know as education, but there is no corporate responsibility for the aggregate of our higher educational institutions. There is no door at which a postman could deliver a registered letter of business.

We may, I think, agree that if we wish for ideals in education in this country we must find them in the Universities. If the Universities give the encouragement of their example and their licence to teach only to men and women who are really educated in the best sense of the word their influence will leaven the whole of education throughout the country; and, on the contrary, if when they leave the Universities the men and women who have to teach, or to control teachers, are themselves imperfectly educated, it is hopeless to expect a well-balanced living educational system. Among the Universities, for reasons good or ill, into which I need not enter, the older Universities of Cambridge and Oxford have a preponderant influence.

And to my mind the outstanding characteristic of the organisation of the older Universities is the want of any recognised door by which their corporate responsibility can be reached. In each case the University is itself a corporate educational institution which includes some twenty Colleges which are also separate corporate educational institutions. You never can tell whether the persons with whom you have business are the University or the Colleges, and it is quite possible that when you think to address the one you find yourself confronted with the other. The Universities in their corporate capacity are constrained by statutes and traditions handed down by our forefathers to look on in comparative impotence while their ideals are distorted or concealed by the interplay of the interests of the many corporations of which they are composed. The whole complex scheme of management forms a sort of craft or mystery which very few even of the initiated really comprehend.

In January of the year when I was writing (1917) I came across two delightful examples of this. The Headmasters' Conference (which consists of men with some academic experience) passed a resolution to the effect that Greek should no longer be required for the entrance examination of the Universities of Oxford and Cambridge, and thereupon the Master of University College, Oxford, spent half a column of 'The Times' in explaining that the University of Oxford had no entrance examination at all.

In the same newspaper Professor Ridgeway, who is Professor of Archæology at Cambridge, and might therefore be supposed to know something about Oxford, wrote a column about Graduate Research, which brought a reply of another column from Professor Percy Gardner, now of Oxford, formerly of Cambridge, to say that so far as Oxford is concerned 'Professor Ridgeway's letter is nothing but a tissue of blunders.' Writing about the same time the Master of a Cambridge College explained to me that everything that appeared in the newspapers about Cambridge was wrong.

This veil of incomprehensibility, the claim to a sort of impenetrable freemasonry or mystery about matters of national concern, is very perplexing for those who want things done in education but do not know the technicalities of the

Universities. It completely hides any door at which the reforming postman might wish to knock. The people who want things done become shy, embarrassed, and intimidated by the people who 'know.' If you want anyone to take in a suggestion you have to seek what an Italian dramatist has called 'la porta di dietro.'

Somehow or other you must get at the Colleges as well as the University. Otherwise you may find yourself addressing the Vice-Chancellor on a subject which is the concern of the Colleges, or addressing the College tutor upon something over which he has no control. For those who know, of course, the explanation is quite simple. The schoolmasters do not want Greek to be compulsory in the entrance examinations of the Universities. We are told that at Oxford, and it is equally true of Cambridge, the University has no entrance examination at all, from which it would appear that the headmasters were at least very ill-informed about the Universities whose practice they wished to modify. Yet the headmasters know perfectly well that their boys, at any rate, have to pass an entrance examination before they can be admitted to either University.

What is true, for Cambridge at least, is that the University *qua* University has no examination for entrance; it is obliged by its statutes to accept as a member without any question anyone presented by the recognised authority of a College, regardless altogether of his qualification or disqualification for a University career. It is a very remarkable arrangement. The University makes no inquiry as to a student's fitness to profit by the educational system of the University : it leaves all that to the Colleges, and many, if not all, of the Colleges have an entrance examination. So I offer this paradox for the logician who is interested in higher education.

The University consists of the members of its constituent Colleges and a few others. At the discretion of the several Colleges, or the non-collegiate students' board, seventy-five per cent. of the members of the University are required to pass an entrance examination before they are accepted for presentation to the University for matriculation. There are at least four examinations of the University which are accepted by Colleges on occasions in lieu of their own entrance examinations. Yet there is no extrance examination for the University.

And this does not end the matter. The University become a controlling body rather than an educational institution with a definite purpose and programme. The regulations for its students are nearly all of them of a negative character. The discipline and the *regimen* of the University rest upon the assumption that a student desires to secure from the University not so much attainment as a stamp for his attainments. A member of the University cannot be admitted to a degree unless he has satisfied certain conditions of residence and also satisfies certain examiners; his name is not accepted for the final examination unless he has satisfied certain other examiners. There is nothing in the regulations or administration of the University to secure that a matriculated student shall study, or aspire to take a degree. He might live on in idleness and ignorance for the rest of his natural life; the University has no choice in the matter so long as his College pays the periodical fees. It trusts to the Colleges to see that idle or unsuitable undergraduates are invited to go elsewhere.

Here we have one of the many instances of the division of jurisdiction between the Colleges and the University which hides the ideals of our system of higher education in an impenetrable fog.

The University is governed by the Colleges according to a system which goes back to the time when the 'Merchant of Venice' was written, so let us revert to the conversation between Portia and Nerissa which expounds the lottery of the caskets in the well-known scene. The position of the University in the matter of the selection or rejection of its members is exactly that which Portia bewailed to Nerissa. Let me invite you to regard the episode of the caskets as a figurative representation of the lottery by which the University of Cambridge selects those upon whom she bestows her inherited riches—'lucem et pocula sacra.' Cambridge, like Portia, the heiress of all the learning of the good and the great, bound by the fantasy of her ancestral tradition never to choose for herself.

Let us think of Portia as the Vice-Chancellor of the University of Cambridge desiring above all things the advancement of learning and of Nerissa as a Proctor whose duty it is, as representing the Senate, the collective body of members of the Colleges, to see that the statutes and ordinances are duly attended to. Listen to the conversation which begins with the exclamation, 'By my troth, Nerissa, my little body is aweary of this great world,' a remark with which I feel sure many a Vice-Chancellor has opened many a conversation with many a Proctor. In accordance with the usual practice in dealing with classical literature I have added a few notes.

Dialogue between Portia (Vice-Chancellor) and Nerissa (Proctor), the representative of the Senate of the University through which the Colleges exercise their control.[1]

Portia (V.C.)—'By my troth, Nerissa, my little body is aweary of this great world.'

Nerissa (Proctor).—'You would be, sweet madam, if your miseries were in the same abundance as your good fortunes are: And yet, for aught I see, they are as sick that surfeit with too much as they that starve with nothing.[2] It is no mean happiness, therefore, to be seated in the mean: superfluity comes sooner by white hairs, but competency lives longer.'

Portia (V.C.).—'Good sentences and well pronounced.'[3]

Nerissa (Proctor).—'They would be better, if well followed.'

Portia (V.C.).—'If to do were as easy as to know what were good to do, chapels had been churches and poor men's cottages princes' palaces. It is a good divine that follows his own instructions: I can easier teach twenty what were good to be done, than be one of the twenty to follow mine own teaching. The brain may devise laws for the blood, but a hot temper leaps o'er a cold decree: such a hare is madness the youth, to skip o'er the meshes of good counsel the cripple.[4] But this reasoning is not in the fashion to choose me a husband. O me, the word "choose!" I may neither choose whom I would nor refuse whom I dislike; so is the will of a living daughter curbed by the will of a dead father. Is it not hard, Nerissa, that I cannot choose one nor refuse none?'

Nerissa (Proctor).—'Your father was ever virtuous; and holy men at their death have good inspirations: therefore the lottery, that he hath devised in these three chests of gold, silver and lead, whereof who chooses his meaning chooses you, will, no doubt, never be chosen by any rightly but one who shall rightly love. But what warmth is there in your affection towards any of these princely suitors that are already come?'

Portia (V.C.).—'I pray thee, over-name them; and as thou namest them I will describe them; and, according to my description, level at my affection.'

We may omit the description of the suitors as they are none of them to her taste, and pass on to Nerissa's remark.

Nerissa (Proctor).—'You need not fear, lady, the having any of these lords: they have acquainted me with their determinations; which is indeed to return to their home and to trouble you with no more suit,[5] unless you may be won by some other sort than your father's imposition depending on the caskets.'

Portia (V.C.).—'If I live to be as old as Sibylla, I will die as chaste as Diana, unless I be obtained by the manner of my father's will.'[6]

As an additional note I should like to suggest that the successful suitor Bassanio with his magnificent thoughtlessness is typical of the Public-School boy for whom the University always plays a soft air when the caskets are in view, but I feel sure my scholastic hearers would detect an anachronism.

I need hardly say that I should not spend so much time over what may

[1] The scene is at Belmont, which is no doubt a poetic name for Market *Hill*, adorned by the University Church in Cambridge.

[2] The University has always been recognised as very poor.

[3] Note the lapse into the sententiousness of the habitual examiner.

[4] This is obviously a reference to University life.

[5] The older Universities have often been thought to be too exclusive.

[6] This is doubtless allusion to the exemplary patience with which the University accepts the 'non placet' of the Senate.

seem to many of you far-fetched, and perhaps unseemly jesting, if I did not believe that this fantastic view of the lottery of the caskets contains the suggestion of an element in the governance of our highest educational institutions which deserves your gravest and most serious consideration. What I have in mind at the moment is the unforeseen and undesired result of the competition of the Colleges within the University itself as quasi-independent educational institutions. It is this small matter, from some points of view of quite minor importance, which, so far as I can see, prevents our great Universities from taking the leading part which they might take in exemplifying the ideals of a co-ordinated national system of education, and makes the success or failure of those great institutions something of the nature of a lottery. They may offer ten thousand different avenues from matriculation to a degree, and yet the student may find himself imperfectly educated in the end.

One may, indeed one must, picture to oneself the idea of the Colleges as a number of educational institutions co-operating in an avowed and transparent common purpose of the University to display the highest educational ideals. So I think if they were willing they might be, without any sacrifice of their individuality or of those magnificent traditions which have fulfilled the high purpose of their pious founders and benefactors. Let us keep that picture for a while in mind.

I have taken out from the Cambridge University Calendar for 1918 a list of subjects selected for teaching in the University and Colleges with the number of Professors, Readers, Lecturers or Teachers assigned to the several subjects. The numbers are given in an Appendix.

If any of my hearers has ever attempted a similar task he will agree with me that the compilation of the list from the information given for the Universities and Colleges is not by any means an easy matter, because the specification in so many instances is indefinite in various ways; but I am not less qualified than the average inquirer, not actually resident in the University, to understand what the information means, and it is for the average inquirer presumably that the Calendar is published. I am, however, not intending to refer to small details, so I hope that the inevitable imperfections, even in so imperfect a year as 1918, will not seriously affect what I have to say.

I find that there are 175 University teachers (professors, readers, lecturers, etc.) and 176 College lecturers. These two classes are certainly not mutually exclusive. In the natural sciences particularly the same names appear in both lists, but, be that as it may, I find that the 175 University teachers between them deal with 73 subjects, an average of $2\frac{1}{2}$ per subject, and are distributed between subjects in the following manner :—

Number of University teachers assigned for a subject

9 8 7 6 5 4 3 2 1

Number of subjects which have the number of teachers specified in the upper line

2 3 1 4 1 3 8 10 42.

The 176 College lecturers deal with only 23 subjects, an average of $7\frac{1}{2}$ per subject. They are distributed as follows :—

Number of College lecturers assigned for a subject

33 30 23 18 17 10 5 3 2 1 ?

Number of subjects that have the number of teachers specified in the upper line

1 1 1 1 1 1 3 1 3 9 6

Here we see at once a great difference between the educational systems. The University is obviously striving to meet as far as possible its higher educational responsibilities. There is great differentiation of duty; 42 teachers are responsible each for a single subject; there are only two cases in which a subject has so many as nine teachers. Whereas in the Colleges the tendency is for the same subject to have a great number of exponents. The favoured subjects are classics 33, mathematics and natural philosophy 30, history and economics 23, natural sciences 18, divinity 17. All those subjects are provided for, to some extent at least, in the programme of the University.

There may be and indeed must be some differentiation within these totals, but it is a differentiation which the College authorities do not think it necessary to disclose. Whatever allowance may be made for that, I think it is obvious that the Colleges tend to repeat many times over a stereotyped form and not to distribute their energies over subjects which for lack of funds or some other reason are not represented in the University list. The list of subjects indicates that the Colleges select the commoner subjects, and are particularly partial to those subjects which do not require any special provision as regards accommodation or equipment. Three subjects appear in the College list and not in the University list—namely, Modern Greek, Celtic, and Military History. Why these subjects are so favoured we need not inquire, but we may be sure that the 176 College lecturers are in themselves fully competent to represent subjects of profound human interest which the University disregards for want of means. That it is the system and not the lecturers that account for this convergence upon a few subjects was evident enough during the war, when Cambridge lecturers were to be found among the most proficient and successful workers with their brains in many departments of activity. The needs of peace are not less urgent than the needs of war; what we have learned in war we ought to practise in peace.

No one can think that the distribution of teachers and subjects would be what it is if the educational system of the University and the Colleges were under the control of a single competent body bent upon manifesting a true ideal of the use of educational endowments, whether in money or men.

Suppose, for example, that the Council of the Senate were recognised as responsible to the country for the educational system of the University and the Colleges jointly; that, once appointed, they were freed from the referendum of every item of their procedure to the lottery of a vote in the Senate. Imagine what would happen if the University really had an entrance examination and the Colleges had to select their members from among the successful candidates. One may speculate upon what such a body would produce, but it is hardly imaginable that they would plump for concentrating so much of the College teaching in general terms upon classics, mathematics, history, and divinity.

And, in support of the contention that diversity of intellectual effort is a pertinent consideration, I would point out that if recondite subjects are to be studied at all it must be at our own great centres of learning. If there is any part of the world where old customs are dying out, or interesting species becoming rare or extinct, it is for highly centralised countries like ours, at a distance from the scene of action, to take care that the subject is studied while there is yet time. On the spot, where no doubt the material is available, people are too much pre-occupied to notice the ultimate effect of their own personal activity. If we should, for example, set about exterminating the vermin of London houses (which, by the way, is above all things a most urgent question of rehousing), it is not from any Londoner nor even from our near neighbours in Cambridge, however interesting the minor horrors of war may be to their biologists, that any protest will be raised about the outrage which the extermination would entail upon the province of natural history.

I have looked through that interesting volume 'The Yearbook of the Universities of the Empire 1914' to see whether the other Universities of this country and the Empire had a notably extended or different range of subjects. The differences are mostly differences in name or in the differentiation of medical and theological subjects. It is interesting to note the gradual formation of University teaching in new lands. It seems to begin with medicine and theology, law, engineering, architecture, commerce, and banking; and next to take in our old college friends mathematics, classics, and natural sciences, but it seldom shows any particular characteristics of local scholarship or specialised learning; but in the older institutions there are some suggestive subjects as Assyrian and Babylonian archæology, classical archæology, African languages (Swahili and Bantu), Irish language and literature, Dutch language and literature, Japanese, Portuguese, Scandinavian languages and Thibetan, phonetics, library science, ancient Indian history and culture, colonial history, Irish history, Scots history, civic design and civic law, scholastic philosophy, Zend philosophy, rhetoric and oratory, geodesies, acoustics, meteorology, and epidemiology in various forms.

Among the subjects which I have noticed in other connections as not represented by name in any of the Universities of the Empire, but still claiming attention of those who would help to make the facilities for education complete, there are in the first place the history of the various arts and sciences, and of medicine, for which some provision has recently been made at Oxford under Dr. Singer; oceanography, which, through the generosity of Professor Herdman, has now obtained a footing in Liverpool; geodynamics, for which Cambridge wishes to make provision, historical geography and exploration; Malay and Polynesian languages and antiquities, aerodynamics, meteorological optics, now neglected in this country; terrestrial magnetism, seismology, climatology (past and present) particularly of the Empire; illumination and photography, metrology, the science of precision, British archæology and dialects; and perhaps the technical subjects of radio-telegraphy, ballistics, and ventilation. These are subjects with which alone a fully equipped University is competent adequately to deal, and the country is ill-provided until the educational authorities co-operate to supply between them what is needed. To secure this object, I am not at all convinced that State aid is the only possibility. The pious benefactor is no more extinct than he was in the days of Henry VIII. and Queen Elizabeth, but while the Universities and their Colleges speak with two voices and leave us uncertain as to their ideals, it is impossible that he should not be discouraged.

The views which I have expressed were formulated and in great part in manuscript while the war was still raging, and now we have celebrated the conclusion of peace. With the signing of the armistice came the demand for an actual address this year. Never in my experience have circumstances been so tragic as those which supervened. The stimulating drama of the war in which good strove with evil gave place to the new conflicts which have the characteristics of real tragedy. In the early part of the new year the hope that the sacrifices of the war would secure an immediate peace was blasted with disappointment. The whole connective tissue of civilisation seemed to be destroyed. The representatives of many peoples great and small assembled at Paris to make peace had first to find some *modus vivendi* for the future, but after a foretaste of a league of nations we found ourselves in a welter of jealousies, animosities, and struggles at home and abroad. Thousands were threatened with distress or with misery by the withholding of the necessaries of civilised life in order to secure the comfort of classes who regarded them as rivals and not comrades in the struggle for existence; the hard-earned savings of industrious lives vanished in taxes to be scattered broadcast as largesse by victorious politicians or grabbed by ruthless profiteers. Food and fuel were obtainable under the strictest limitations and under conditions apparently designed to be nearly intolerable; the aged and infirm were bereft of all the kindly offices that carry the sacred name of service; teachers abandoned their schools in order to settle a dispute about salaries.

We had just learned in the great school of experience that united self-sacrifice, and nothing short of it, could and did secure a victory over the powers of evil; and thereupon the whole world seemed obsessed with the idea that, the war being over, the time for sacrifice was done with; we could almost hear the many-voiced assertions of nations, of unions, of commercial associations, and of men and women generally, that as their sons and brothers had made the great sacrifice never again could they be expected to make another in this world. The elements themselves seemed to play their part in prolonging and deepening the gloom, and, as if impatient of the natural order, kept the world dead, cold, and miserable, far beyond the limits of an ordinary winter —in those circumstances, doleful beyond expression, what could be said about education. What ideals of education had led us to such a state of chaotic conflict of wills. It seemed impossible that mankind could ever recover and resume its sane and wholesome life of reciprocal give-and-take.

And in the midst of the gloom came a glimpse of Easter sunshine, and once more we heard the Easter words which have been the first audible sentence of many a mournful scene, 'I am the Resurrection and the Life.' What do they mean for us who have to try to live in this torn and distracted world? 'There will be no reconstruction and there can be no wholesome life for us or for anybody else without the spirit of self-sacrifice.' If the world takes the facile

view that self-sacrifice was over and done with when the last shot was fired at Mons, we are lost. We knew well enough that, whatever we may have done at home, without the sacrifice of our brothers at the Front and on the seas, we should have perished. And after that have we to learn the law of life, that we in our turn must go on bearing our part?

It is so obviously true. Look where you will, life is based on sacrifice for some ideal of duty. If each of us does no more than is required for our immediate necessities we cannot live. That is a commonplace of individual life, but in large measure we seem to forget it or ignore it in a corporate capacity. People will permit, as corporations or as a nation, inhumanities of which each individual would be ashamed. The Hebrews have given us a decalogue for individuals which at least satisfies the moral sense of the world. If it were not given by inspiration it must have been supplied by the simplest process of inductive reasoning. Without it social life is not possible. The sense of duty to our higher selves and our neighbours is our only sure guide. But now we want a decalogue for unions and corporations, for combines and nations.

To satisfy this imperative want we depend upon education. And therefore, by a simple generalisation, the educational corporations ought to show us the ideals of the principles and practice of a new code of conduct. And that is so because, at least in education and educational affairs, self-sacrifice must be obvious if there is to be real educational life. No teacher can ever teach anybody anything worth having who does not carry the signs of sacrifice in his teaching.

No body of teachers and no institution can really make a living education unless they are animated by that spirit. The ideals of education are not salaries and can never be attained by striking. I admit that when you are dealing with corporations the language is difficult. I do not quite know what a self-sacrificing county council would be, but I am perfectly certain that there can be no true social life which is based entirely upon the principle of inexorable contracts and has no room for humanity, for the give-and-take of self-sacrifice.

But all this must be, not for vanity, but for an ideal of duty that commands acceptance as true. Effective self-sacrifice does not mean non-resistance at all times and in all circumstances. In a conflict of ideals, as we have learned from the war, the most effective form of self-sacrifice may be to put one's self in a position to kill as many of the enemy as one can. And, in so far as the ideals have truth and vitality, they will evoke true loyalty. Consequently for all educational institutions the most important consideration is that they should manifest their ideals to be such as evoke from each the sacrifices which make for ordered life.

As one passes in review our own educational institutions one may judge of their ideals by their results. Judging in that way and looking at the education of our Public Schools we may fairly say that the social or ethical ideal is splendid. It expresses the principle of excellence which I take to mean success in fair competition. It is no doubt Hellenic rather than Christian, it is based upon the literature of the ancient Greeks, and has still strength enough to call forth the most devoted self-sacrifice. In the Universities also the same ideal is quite easily recognised. There, if anywhere, you can see the worship of success in fair competition developed into a real religion. For a long time I have thought that we should be much nearer understanding our real position in these things if we could persuade the classical scholars to do for Greek religion what the compilers and translators of the Bible did for the Hebrew. That is to collect together in the best available translation the literature of the Greeks which formed the basis of their guides to conduct. The appropriate contents of such a collection were sketched out by Dr. James Adam, a College colleague of mine at Cambridge, whose untimely death is still deplored, in his Gifford lectures on the Religion of the Greeks. With him the subject was a source of unbounded enthusiasm, and his lectures are a series of sermons on the testament of the Greeks. But we ordinary readers, unlearned in the Greek literature, are in the position of those who are offered sermons on the Old Testament instead of the Old Testament itself. If you imagine where we should stand if the Old Testament were denied to us except in the original Hebrew, you will understand the position the vast majority

of us must occupy with regard to Greek ethics, which are in fact the ethics of our ruling classes in the old sense. Therefore I use this opportunity to beg those who are enthusiastic for Hellenistic studies to give us such a testament. I feel sure it will enable us to understand the ideals of the Public Schools and Universities and throw an entirely new light upon the supposed conflict of classical and scientific studies, which is possibly only another phase of the other perennial dispute about religious education.

The ethical ideals of our schools and Universities are clear, excellent in themselves, and appreciated everywhere. They manifestly excite enthusiasm and develop the spirit of self-sacrifice for their maintenance. But what of the intellectual ideals? The subject is important because the cultivation of the intellect is the avowed purpose of academic institutions, and is the part of education which is necessary for carrying on the world's work. Looking at the actual practice of the Universities we can see that the intellectual ideals are obscured, confused, and enfeebled by the very process of competition between Colleges which is so eminently successful in developing the ethical spirit.

But the opportunity for strengthening and clearing our intellectual ideals is now. It may require some sacrifice of prejudices and traditions as between Colleges and the University, but the reward will certainly be great.

I suppose that a century ago the character of any distinguished educationalist would be summed up in the words 'He spared not the rod'; and to-day perhaps the highest praise is expressed by saying that 'He spared neither the ratepayer nor the taxpayer,' but even that is not enough. Money without motive power does not make education. We may reserve our highest praise for those educational establishments of which it may be said that in the pursuit of a true ideal they spared 'neither their prejudices nor their inherited privileges.' It may sound sacrilegious, but it must be said—the Portia of our dreams will not become the Alma Mater that the nation needs if she can never be obtained except after the manner of her father's will.

APPENDIX.

TABLE OF SUBJECTS OF LECTURES AND THE NUMBER OF PROFESSORS AND TEACHERS THEREIN IN THE UNIVERSITY AND COLLEGES OF CAMBRIDGE.

(*Taken from the Cambridge University Calendar*, 1918.)

Degrees and Diplomas	Subjects	University Teachers			
		Professors and Readers	University Lecturers and University Teachers	Total (University)	College Teachers
D.D., B.D., M.A. Certificate	DIVINITY	5	1	6	17
LL.D., LL.B., M.A.	LAW (including International Law)	3	1	4	10
	Indian Law	—	1	1	—
M.D., M.B., M.S., Ch.B.	MEDICINE AND SURGERY—				
	Physic and Medicine	2	2	4	—
	Vaccination	—	1	1	—
	Anatomy	1	8	9	—
	Surgery	1	1	2	—
	Pathology	1	3	4	—
	Medical Chemistry	—	1	1	—
	Medical Jurisprudence	—	1	1	—
	Medical Entomology	—	1	1	—
	Pharmacology	—	1	1	—
Diploma	Tropical Medicine & Hygiene	—	—	—	—
	Carried forward	13	22	35	27

TABLE OF SUBJECTS OF LECTURES, ETC.—(*continued*).

Degrees and Diplomas	Subjects	University Teachers: Professors and Readers	University Teachers: University Lecturers and University Teachers	University Teachers: Total (University)	College Teachers
	Brought forward.	13	22	35	27
Diploma	PUBLIC HEALTH—				
	Hygiene	—	1	1	—
	Chemistry of Hygiene	—	1	1	—
Sc.D., M.A.	PHILOSOPHY—				
	Moral Sciences—				
	Philosophy of Religion	—	1	1	—
	Moral Philosophy	1	—	1	—
	Mental Philosophy	1	—	1	—
	Psychology	—	3	3	—
Diploma	Psychological Medicine	—	—	—	—
	Mathematics and Natural Philosophy—				
	Mathematics	2	6	8	30
	Astronomy	2	—	2	—
	Statistics	—	1	1	—
	NATURAL SCIENCES	—	—	—	18
	Physical Sciences—				
	Experimental Physics	1	5	6	1
	Chemistry	2	7	9	—
	Mineralogy	1	1	2	—
	Metallurgy	1	—	1	—
	Astrophysics	1	1	2	—
	Geology	1	5	6	1
Diploma	Geography	—	3	3	—
	Biological Sciences—	1	2	3	2
	Botany	2	5	7	1
	Physiology	1	7	8	2
	Zoology	2	6	8	1
	Biochemistry	1	—	1	—
	Anthropology	—	1	1	—
	Genetics	1	—	1	—
	LETTERS—				
	Classical Studies—				
	Classics	2	—	2	33
	Comparative Philology	1	—	1	—
	Paleography	1	—	1	—
	Greek	1	—	1	—
	Latin	1	—	1	—
	Ancient History	1	—	1	—
	Archæology	2	—	2	—
	Ethnology	1	—	1	—
	English—				
	Anglo-Saxon	1	—	1	—
	English Literature	1	1	2	2
	English	—	1	1	—
	Modern and Mediæval Languages	—	—	5	—
	German	1	—	1	—
	Carried forward	47	80	132	118

TABLE OF SUBJECTS OF LECTURES, ETC.—(*continued*).

Degrees and Diplomas	Subjects	University Teachers: Professors and Readers	University Teachers: University Lecturers and University Teachers	University Teachers: Total (University)	College Teachers
	Brought forward	47	80	132	118
	Romance	1	—	1	—
	French	—	—	—	—
	Russian	—	1	1	1
	Italian	—	1	1	—
	Spanish	—	1	1	—
	Modern Greek	—	—	—	1
	Celtic	—	—	—	1
Diploma	*Oriental Languages*—				
	Hebrew	2	1	3	5
	Arabic and Turkish	2	1	3	—
	Chinese	1	—	1	—
	Persian	—	2	2	—
	Indian Languages—				
	Sanskrit	1	1	2	—
	Hindustani	—	1	1	—
	Bengali	—	1	1	—
	Marathi	—	1	1	—
	Burmese	—	1	1	—
	Talmudic	—	1	1	—
	Bibliography	1	—	1	—
	HISTORY AND ECONOMICS	2	—	2	23
	Ecclesiastical History	1	—	1	—
	Indian History	—	1	1	—
	Military History	—	—	—	1
	Political Economy	1	2	3	5
Mus.Doc., Mus.Bac.	MUSIC	1	2	3	3
	TECHNICS—				
M.A.	Engineering	2	4	6	5
Diploma	Mining Engineering	—	—	—	—
Diploma	Agriculture	3	2	5	—
Diploma	Forestry	1	2	3	—
Certificate	Education	—	1	1	—
	ART AND ARCHITECTURE—				
Diploma	Fine Art	1	—	1	—
	Lectureships with no Subjects assigned	—	1	1	6
	Number of Teachers	67	108	176	145
	Number of Subjects	—	—	(73)	(23)

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ADDRESS

TO THE

AGRICULTURAL SECTION

BY

PROFESSOR W. SOMERVILLE, D.Sc.

PRESIDENT OF THE SECTION.

Grass.

DURING the past four years—or since the ploughing programme began to take shape—grass land has been officially cold-shouldered in no small degree. The cause was obvious and the reasons were good. The result of compulsory and voluntary ploughing has been that whereas in 1914 the total area in Great Britain under temporary and permanent grass (hay and pasture) was practically $21\frac{1}{2}$ million acres, it was barely $19\frac{1}{2}$ million acres in 1918, a reduction, namely, of about 2 million acres. During the same period the arable area, other than temporary grass, increased from about $10\frac{1}{2}$ million acres to $12\frac{1}{2}$ million acres. In Ireland, during these years, the area under grass (permanent and temporary) fell from about $12\frac{1}{2}$ million acres to less than $11\frac{1}{4}$ million acres. The United Kingdom at the present time comprises about $30\frac{1}{2}$ million acres of permanent and temporary grass and $15\frac{1}{2}$ million acres of land under crops other than grass and clover. This is over and above some 16 million acres of mountain land used for grazing.

It is far from my intention to attempt to maintain that grass land is, as compared with tillage, defensible from the point of view of national economy. It has been proved conclusively by various writers, and by none more convincingly than by Sir Thomas Middleton, that in respect of nutritive output, and the utilisation of labour, and in its bearings on foreign exchange, arable cultivation is much more attractive than pastoral farming. It is my sincere hope that the Royal Commission now sitting will be able to formulate a policy, acceptable to the Government, which will result in the retention for tillage of at least all that the plough has gained during the war, and, in my view, it would be well for the country if a much larger area even than that could be wrested from the grazier. But for the moment the tendency is in the other direction, and under the stimulus of high wages, and increased costs generally, a certain amount of land has already been resown to grass, and preparations are being made for similarly dealing with an increased area next spring. It would, therefore, appear that under any circumstances that can be conceived the area of land under grass is likely to remain at a very high figure, and to be well worth the consideration of this Section of the British Association.

A considerable proportion of the grass land of this country is of so high a quality that any improvement, and certainly any economic improvement, is hard of accomplishment. Satisfactory as are the high-class pastures of this country, it by no means follows that there is nothing more to learn about them. Grazing practice is in general agreement that the productive capacity of these pastures is maintained by judicious stocking during the growing season, by the regular mowing of thistles and other coarse weeds, by the maintenance of the drains (if such exist), by the spreading of the droppings of cattle, by the avoidance of winter grazing (at least in the case of land liable to 'poach'), and, in many cases, by the consumption of a certain amount of cake, at least during the

latter part of the season. On many of the high-class pastures no cake is used, so that the annual drain of nitrogen and minerals in the form of animal disease must be balanced—if fertility is maintained unimpaired—by the nitrogen gained in various ways from the air, and by the weathering of inert mineral matter in the soil. As, however, 300 lb. of live weight 'fattening' increase per acre per annum—which may be assumed to be about the maximum production of high-class pasture—will contain only about 3 lb. of nitrogen and a similar amount of mineral matter, the natural agents will have no difficulty in replacing this loss. It would appear in fact that, but for the loss of plant food by drainage and denitrification, even a fattening pasture should go on improving, and this is the case so far as accumulated fertility is concerned, though not in respect of current or immediate animal production. On a pasture of naturally low quality, where leguminous herbage stimulated by phosphatic manuring is the main factor of value, it has been proved at Cockle Park that the addition of nitrogen either as artificial manure or in the form of cake residues has been positively injurious or has produced a result disappointingly small, and one would like to see this subject followed up experimentally in the case of naturally rich pastures where cake is freely used. One would like to study in detail the effects of phosphate and potash on such land, although where production is naturally so high it is unlikely that it can be materially and economically increased.

It is often very difficult to determine the factor or factors that go to the making of high-class pastures. Such pastures are to be found on most of the geological formations of this country; they are met with north, south, east, and west; and even altitude, within the limit of at least seven hundred feet, seems to have little effect. An immense amount of attention has been given to the botanical composition of the herbage of the more famous of the pastures of Britain. Notable in this connection is the work of Fream,[1] Carruthers,[2] Hall and Russell,[3] and Armstrong.[4] The methods employed varied to some extent with the investigator. Fream had turfs dug up and transferred to Downton, where they were planted in the garden, the herbage being subsequently clipped over and separated; Carruthers, Hall and Russell relied partly on enclosing representative areas and sampling the herbage when well grown, and partly on occular estimation; while Armstrong used a frame a foot square divided by transverse strings into 144 square inches. This was placed on the sward *in situ* and a note made of the percentage occurrence of the different species of plant. The result that emerges most conspicuously from these researches is that one may have a dozen pastures, which are about equal in feeding value, and yet which may vary widely in respect of botanical composition. Thus Fream found that in the case of forty-eight English and eight Irish pastures, each of which was the 'best' in the district selected, the Gramineæ might be as low as 11 per cent. and as high as 100 per cent.; Leguminosæ might be entirely absent or as high as 38 per cent.; while of miscellaneous herbage, most of which would be designated as 'weeds,' there might be none or up to 89 per cent. As regards individual genera and species, Fream found, for instance, that Agrostis was almost always present and on five occasions was the most abundant plant; while *Holcus lanatus* gave an almost identical result. By a different method Carruthers arrived at a very similar conclusion. The latter also found that *Hordeum pratense* was the most abundant species on what is perhaps the finest grazing in England, namely, Pawlett Hams, near the mouth of the Parret in Somerset. This investigator even found that on one of the 'Famous Ancient Pastures of England' the pre-

[1] W. Fream, 'The Herbage of Old Grass Lands,' *Jour. Roy. Agric. Soc. Engl.*, vol. xxiv., 2nd Series, p. 415; and 'The Herbage of Pastures,' *Jour. Roy. Agric. Soc. Engl.*, vol. i., 3rd Series, p. 359.

[2] W. Carruthers, 'The Composition of Some of the Famous Ancient Pastures of England,' *Jour. Roy. Agric. Soc. Engl.*, vol. i., 3rd Series, p. 751.

[3] A. D. Hall and E. J. Russell, 'On the Causes of the High Nutritive Value and Fertility of the Fatting Pastures of Romney Marsh and other Marshes in the S.E. of England,' *Jour. Agric. Science*, vol. iv., p. 339.

[4] S. F. Armstrong, 'The Botanical and Chemical Composition of the Herbage of Pastures and Meadows,' *Jour. Agric. Science*, vol. ii., p. 283.

dominant grasses were Fiorin and Hassock, and in this connection makes the following remark, 'In this field the hassock-grass, which made up a large proportion of the pasture, was freely eaten, and the cattle were in good condition.'

In Hall and Russell's investigations Agrostis and Holcus might on occasion each exceed 20 per cent., and it is stated that 'Wherever *Holcus lanatus* occurs it is more abundant on the fatting fields.' Even miscellaneous herbage could bulk over 29 per cent. on a pasture so good that it could fatten five bullocks on four acres without cake. Armstrong found in a field representative of 'the richest type of old grazing land found in the Market Harborough district' that, amongst grasses, *Poa annua* came second (12·3 per cent.) in point of abundance; while in two meadows, also in Leicestershire, the one representative of 'the choicest meadow land of the neighbourhood,' and the other 'a meadow of above the average quality,' the grasses were 41·5 per cent. and 70·3 per cent. respectively, in the second case Agrostis amounting to 12·7 per cent. There will be general agreement in this audience that four of the grasses just mentioned, Fiorin, Yorkshire Fog, Squirrel Tail, and Hassock are accounted 'bad,' and yet it is hard to apply this term to plants which are the most abundant constituents of some of the finest pastures in England. While there is much that is disconcerting in these investigations, some facts do emerge with satisfactory consistency, (1) that the great majority of high-class pastures contain a large proportion of perennial ryegrass and white clover, (2) that crested dogstail is almost always present though rarely predominant, (3) that meadow fescue is practically negligible, and (4) that of the two Poas, pratensis and trivialis, the former is very rare, while the latter is very common.

The obvious deduction to be drawn from these investigations is that the quality of a permanent pasture is only in a minor degree determined by the relative abundance of its constituent plants, or, in the words of Hall and Russell, 'We can only conclude that the feeding value of a pasture is largely independent of the floral type.' Factors of much greater weight are depth and physical character of the soil, soil moisture and temperature, density of the herbage, and the natural or induced composition of the soil as regards plant food, and especially in respect of phosphoric acid.

That much seems to have been proved, but, such proof notwithstanding, I cannot think we are justified in going so far as Carruthers, when he says, 'The composition of the pastures shows the fallacy of seeking in natural pastures the standard for laying down arable land in permanent grass. The adoption of such a standard is to reverse the whole practice and principles of modern farming.'

It seems to me that the lesson that may be learned from a study of the old pastures of England is that we need not include in a seeds mixture for permanent purposes plants which never bulk to any considerable extent in old grass land, but that we should include all of those which are usually naturally abundant. Take, as an illustration, the case of perennial ryegrass. In the eighties of last century, when much interest was taken in the subject of the best way to lay down land to grass, an almost violent controversy arose over the desirability or otherwise of including perennial ryegrass in a seeds mixture for permanent pasture. The main opponents of ryegrass were Faunce de Laune and Carruthers, who would have excluded this species under all circumstances. The work of Lawes, published under the title 'The History of a Field newly laid down to permanent grass,' [5] also tells against ryegrass, though it is to be noted that the field in question, sown down in 1859, was mowed every year, and there is some reason to believe that this grass is more persistent in a pasture than in a meadow.[6] On the other hand, we have the evidence of a series of experiments laid down by myself in Huntingdonshire in 1900 and reported on in 1905 by Biffen [7] and Middleton,[8] which shows that under certain

[5] *Jour. Roy. Agric. Soc. Engl.* 1889, p. 1.

[6] R. G. Stapledon and T. J. Jenkin, 'Pasture Problams'; *Jour. Agric. Science*, vol. viii., p. 53.

[7] Cambridge University Department of Agriculture Guide to Experiments, 1907, p. 104.

[8] T. H. Middleton, 'The Formation of Permanent Pastures,' *Jour. Board of Agric.*, vol. xii., pp. 385 and 449.

circumstances (in this case Oxford clay) perennial ryegrass does maintain and even improve its position. It is, however, a common experience of those who have laid land away to grass with ordinary commercial seed that perennial ryegrass does not persist,[9] but neither, for the matter of that, does white clover. And the probability is that the cause in both cases is to be found in the same direction. Both these plants, as usually grown in this and other countries for seed, are the progeny of a long line of cultivated ancestors, grown under somewhat forcing conditions which may be said to undermine the 'constitution.' They have adapted themselves to their artificial environment, and such adaptation has taken the form of early maturity and the production of a large yield of 'bold' seed which is easily marketed. Gilchrist has, of late years, directed attention to the merits of wild white clover,[10] which, as regards persistency, is on an altogether different plane from the cultivated or Dutch white. The price that farmers are willing to pay for the seed of wild white clover is the best proof of the sharp distinction which they draw between the two varieties. What we now want is similar work on grasses, and particularly on perennial ryegrass, and it is satisfactory to know that such work has actually been started.

Other lines of investigation associated with the creation of permanent pasture that might repay research are the relative nutritive values of the more important pasture plants when grown under precisely similar conditions, as also under conditions of soil and climate with which they are naturally associated, and when subjected to the actual process of grazing. In 1853 Way published an account of his analysis of grasses, clovers, and other pasture plants,[11] a line of inquiry that was again followed by Voelcker[12] some thirty years later. In the former case the plants were collected as they grew naturally in the field, while in the latter they were specially grown in plots. A comparison of the two sets of figures does not reveal any consistent agreement, a result that seems to support the view that, in respect of nutritive value and mineral contents, grasses are very sensitive to soil conditions and other factors of the situation. The difficulty of determining the feeding value of pasture by means of chemical analysis was experienced in a marked degree by Hall and Russell, who thus express themselves[13]: 'The only general conclusion one can draw is that the method of food analysis as ordinarily practised gives no measure of the feeding value of such material as grass. It fails to reveal anything to correspond to the very marked differences in habit of the fatting and non-fatting grasses, and none of the results can be interpreted so as to show which of the grasses were poor and which valuable food. . . . Although the difference in feeding value was known to be great, the differences revealed by the ordinary methods of chemical analysis were very small. The ordinary methods are clearly inadequate for dealing with pasture grasses.' It would therefore appear that if further attempts are to be made with a view to differentiating between the various pasture plants in respect of nutritive value, resort will have to be had to the digestive track of animals on lines suggested by the Tree Field Experiments at Cockle Park. Areas large enough to provide grazing for a sufficient number of sheep, and, *a fortiori*, of cattle, present a serious difficulty, and the idea suggests itself that perhaps guinea-pigs or rabbits could be utilised as the medium in small-scale experiments. I should also like to see a test made of the effects of sowing the mixed seed derived from the herbage of good grass land fortified with a pound per acre of the seed of wild white clover, in contrast with a mixture of seeds compounded on the most so-called scientific principles. Nearly twenty years ago I took over a heavy farm on the Weald and created as good pastures as, I believe, the land could carry by applying 7 cwt. of basic slag to the foul stubbles without the

[9] Stapledon and Jenkin, *op. cit.*, p. 26.

[10] D. A. Gilchrist, 'Trials of Wild White Clover.' *Jour. Board of Agric.*, vol. xxii.

[11] J. Thomas Way, 'On the relative Nutritive and Fattening Properties of different Natural and Artificial Grasses,' *Jour. Roy. Agric. Soc. Engl.*, vol. xiv., p. 171.

[12] M. J. Sutton, 'Permanent Temporary Pastures,' 1st Ed., 1886.

[13] *Op. cit.*, pp. 369 and 370.

addition of any seed whatever. I have seen a field of excellent pasture so uniform throughout that no one in a company of farmers and scientific agriculturists could tell any difference between one side and the other, and yet one part of the field was seeded with the most perfect mixture which a leading seedsman could devise, while the other part got no seed at all. The whole field, however, had been well dressed with basic slag. I have still a vivid recollection of sowing down 46 acres to grass in the spring of 1901 on the University Farm at Cambridge. The seed [14] was put in with a thin cover crop of peas and oats, and the weather subsequently proving extremely unsuitable for germination and growth. In July the whole area was a mass of weeds, and few, if any, of the grass and clover plants introduced as seed had persisted. A more derelict-looking piece of ground it would be hard to imagine, and the mowing machine was run over it to clear up the rubbish. But from such an unpromising beginning an excellent pasture has resulted, in my opinion phosphatic manuring, not the primary seeding, being the determining factor.

These are the kind of results that cause one 'furiously to think' whether it is not worth while to investigate along the lines indicated, even if these appear to conflict with conventional practice. For this suggestion I hope I may claim the support of Stapledon and Jenkin, who say, in connection with white clover, 'On many types [of soil] phosphatic manure [is] all that is necessary to hasten the appearance of the indigenous plant,' and, further, 'Undoubtedly when putting land down to long duration grass as much or more can be done by making the habitat as suitable as possible to the desirable indigenous species, as by including their commercial counterparts in the mixture.' [15]

Important as is the position of the fine old pastures of England in the agricultural economy of the country, and interesting though it may be to examine questions of seeding, a much more important line of inquiry is opened up by the problem of the improvement of our second- and third-rate pastures. What proportion of the grass land of the country falls into the lower categories it is impossible to say, but the most superficial acquaintance with rural England is sufficient to carry conviction that the aggregate area of such land is enormous. Most of the poor grass land of the country is associated with the heavier classes of soil, and has been abandoned to grass on account of the high costs of cultivation, including, in many cases, the necessity of drainage. It is, for arable purposes, essentially wheat land, with an occasional crop of beans, and the regular intervention at comparatively short intervals of a bare fallow. Other areas of poor pasture, smaller in aggregate extent than the clays, but still of much importance, are to be found on all the geological formations of the country. Of the 14½ million acres of permanent grass in England and Wales, 70 per cent. is under pasture and only 30 per cent. under hay, and of the poorer classes of grass land it is certain that the proportion that is grazed is still greater. It is evident therefore that the improvement of pasture is relatively a more urgent matter than the improvement of meadows, though with over 4¼ million acres of permanent grass made into hay in England and Wales during 1918, the latter problem is also one of enormous importance. The most famous experiments on the effects of manure on permanent hay are those started in 1856 by Lawes and Gilbert on the Meadow at Rothamsted, and continued ever since on the lines originally laid down. The results have thrown a flood of light on the principles of manuring, which has been of the greatest assistance in the elucidation of problems in agricultural chemistry and soil physics. They have also shown unmistakably the effects of the more important elements of plant food on the yield of hay and on its botanical composition, but even supported as they were by elaborate chemical analysis of the produce, they leave us uncertain in regard to the feeding value of the herbage.

A very large number of experiments have been carried out which had for their object the determination of the quantitative results attributable to the use of manures, singly and in combination. In many cases these experiments were supported by a botanical and not infrequently by a chemical analysis of

[14] Cambridge University, 'Guide to Experiments at Burgoyne's (University) Farm,' 1906, p. 72.

[15] *Op. cit.*, pp. 61-62.

the resultant herbage, but it was felt that we were still in a state of much uncertainty in respect of the quality of the hay, that is to say, its effect on animals consuming it. This induced Middleton [16] in the winter of 1900-1 to carry out a feeding experiment with sheep at Cockle Park, and in 1905-6 and 1907-8 Gilchrist [17] continued and amplified this work. The sheep were accommodated in a special house. The various lots of sheep all got equal quantities of roots, cake, and hay. The hay employed was the produce of variously manured plots on old grass land which I laid out in 1897. The soil is a clay loam on a boulder clay subsoil. This set of experiments includes the eight-plot test, and it may be interesting to see what influence nitrogen, phosphoric acid, and potash respectively have on the produce. The quantitative figures refer to the average annual yield for 21 years, 1897-1917, while the figures which indicate the relative values of the produce, as determined by the live weight increase of sheep, are based upon the feeding tests already specified. The hay from the unmanured plot, No. 6, is assumed to be worth 4*l*. per ton. The results are set out in the accompanying table.

Plot	Manuring per acre per annum	Average Annual Yield of Hay	Value per Ton of Hay as determined by feeding
		cwt.	
6	Unmanured	$19\frac{1}{4}$	80/-
7	30 lb. N in Sulphate of Ammonia .	23	72/-
8	50 lb. P_2O_5 usually in Basic Slag .	26	93/-
9	50 lb. K_2O in Muriate of Potash .	16	80/-
10	30 lb. N+50 lb. P_2O_5 . . .	$30\frac{1}{4}$	84/-
11	30 lb. N+50 lb. K_2O . . .	21	72/-
12	50 lb. P_2O_5+50 lb. K_2O . .	26	101/9
13	30 lb. N+50 lb. P_2O_5+50 lb. K_2O .	$30\frac{1}{2}$	89/2

Nitrogen derived from sulphate of ammonia, and used at the rate of 30 lb. per acre per annum, has consistently increased the yield and as consistently reduced the quality. When used alone the nitrogen has increased the crop by $3\frac{3}{4}$ cwt. per acre, and reduced the feeding value of the hay by 8*s*. per ton. When added to phosphates the nitrogen has increased the yield by $4\frac{1}{4}$ cwt. and reduced the quality by 9*s*. per ton. When nitrogen was added to potash the yield has been raised by 5 cwt. per acre, and the value lowered by 8*s*. per ton. When used as an addition to both phosphates and potash the nitrogen has increased the yield by $4\frac{1}{2}$ cwt. per acre, while the value has fallen by 12*s*. 7*d*. per ton. Even if the quality of the hay be disregarded, the use of nitrogen has always been attended by an adverse financial balance; when quality is taken into account this undesirable result is greatly emphasised.

As regards phosphoric acid, an increased yield has been consistently obtained by its use, accompanied in every case by a marked improvement in the quality of the hay. Taking the arithmetical mean, the increase in quantity has been nearly $8\frac{1}{2}$ cwt. per acre, while the increase in quality is represented by 16*s*. per ton.

The behaviour of potash is rather peculiar. It has quite distinctly reduced the yield when used alone or when used in combination with nitrogen only, while under both these sets of circumstances it has had no influence one way or other on the quality of the hay. When added to phosphates it has proved powerless to increase the yield, but it has raised the feeding value of the hay by 8*s*. 9*d*. per ton. When added to both nitrogen and phosphates the potash has been practically inoperative so far as yield is concerned, but it has improved the quality by 5*s*. 2*d*. per ton.

These results show that very erroneous conclusions may be reached if, in experimental work on meadow hay, attention is only given to the weights of

[16] *Sixth Annual Report on Experiments . . . at Cockle Park*, 1902, p. 19.

[17] *Bulletin No. 8 of Northumberland Education Committee*, 1906, p. 69; and *Guide to Experiments at Cockle Park for* 1916, p 30

produce secured. Thus, in these Cockle Park experiments, on the average of 21 years, if quantity alone be regarded, sulphate of ammonia used by itself has involved an annual loss of 6*s*. 4*d*. per acre, whereas, if the reduced quality of the hay be taken into account, the loss is increased to 15*s*. 7*d*. per acre. On the other hand, a quantitative gain of 4*s*. 2*d*. per acre per annum from the use of phosphate and potash is raised to one of 32*s*. 5*d*. owing to the superior quality of the hay. While there is a certain relationship between the chemical composition, the botanical analysis and the feeding value of the hay there will probably be general agreement with Middleton when he says that 'Without an appeal to the animal the relative values of samples grown under different treatment cannot be measured.' In my view this form of research may, with advantage, be largely extended.

It is unnecessary to attempt to abstract the numerous permanent hay experiments which have been a prominent feature of field-plot trials, especially during the past thirty years. These show unmistakably that farmers of meadow land have an attractive opportunity for the judicious expenditure of capital on artificial manures. It is an opportunity which most progressive farmers have embraced, though the condition of wide areas of meadow land shows how much still remains to be accomplished. Broadly speaking, phosphates are the foundation on which manurial improvement is most surely laid, supplemented in most cases by nitrogen, and in many cases by potash. There are numerous instances throughout the country of phosphates alone producing the maximum return in profit and quality, and sometimes even in weight. Thus on a field in East Suffolk, 'of very poor, heavy land that had been untenanted for some years at Rendham and apparently grew nothing but wild carrots and a little rough grass,'[18] quarter-acre plots were laid down in the autumn of 1900. 'The hay crop of 1901 was so poor that it was not considered worth weighing.' But in the subsequent five years the results were very remarkable, the average yield on the unmanured area being 8 cwt. of hay, as contrasted with 35 cwt. on the plot which received a single dressing of 10 cwt. of basic slag. Taking hay at 2*l*. per ton, and therefore making no allowance for the superior quality of the produce, or for residues, the slag gave a return, after deducting its cost, of 12*l*. per acre.[19] But the apparent lack of the need of phosphates for support from added nitrogen is usually associated with the earlier years of such experiments, and such need disappears later. Hall accounts for the superior early action of the phosphate as follows: 'It is not uncommon to find cases where the application to grass land of a phosphatic manure, like super-phosphate or basic slag, is followed by a great increase of crop, the addition of the phosphoric acid to the dormant nitrogen and potash in the soil having supplied the missing element in a complete plant food. . . . A nitrogenous manure alone is often thought exhausting, but probably a phosphatic manure used singly will even more quickly impoverish the soil.'[20] I agree that this argument applies to tillage land growing non-leguminous crops, but it seems to be put too strongly in the case of permanent grass land. In my view the more marked effects of phosphates in the earlier years is due to the fact that when one applies phosphates one is indirectly applying nitrogen as well. But after the first great flush of clovers, and of Leguminosæ generally, this class of plant becomes less abundant, and consequently the fixation of atmospheric nitrogen by the herbage is reduced, and the crop requires and responds to nitrogenous manures. Where, however, there are abundant natural supplies of potash in the soil the stage of marked reduction in fertility of a hay field may be long delayed. Thus on Palace Leas, at Cockle Park, the plot which for over twenty years has annually received nothing but phosphates is showing a larger increase in the hay crop on the average of the last five years than it did on the average of the first five. And not only so, but the addition of

[18] *Report, East Suffolk County Council*, 'Field Experiments, How very poor heavy land Pasture may be improved.'

[19] Cambridge University Department of Agriculture, 'Guide to Experiments,' 1907, p. 150.

[20] A. D. Hall, 'The Manuring of Grass Land,' *Jour. Roy. Agric. Soc. Engl.*, 1903, p. 76.

sulphate of ammonia had distinctly more influence in the first five than in the last five years, and this not only when used alone, but also when it was added to phosphates only, to potash only, or to phosphates plus potash. It would appear, therefore, that here at least—and there must be many other instances—the persistent use of phosphates has not only *not* tended to exhaust the soil of nitrogen, but has positively increased it. By way of measuring the extent of the stored-up fertility in grass land that has been treated with phosphates, I carried out a series of pot experiments on the following lines: Five lots of soil and turf from treated and untreated land from the same fields were placed in pots in which five crops of cereals and mustard were subsequently grown, when it was found that on the average the yield was increased by 27 per cent. This result was quite in conformity with the increase of nitrogen in the soil as disclosed by chemical analysis.[21]

Turning now to the improvement of pastures, as contrasted with meadows, it may be remarked that while no sharp line can be drawn between these two classes of grass land in respect of ameliorative treatment, there are certain distinctions which must be kept in view. In a meadow the plants are allowed to grow up to full maturity, whereas in a pasture they are cut over daily, or at least very frequently, by the grazing of the animals. It is difficult to arrive at a decision as to whether a larger gross weight of dry material is got from a given area treated as pasture, in contrast to being hayed, but the probability is that the aggregate quantity is greater. Take the analogy of a patch of lucerne. Cut three or four times in the season it may yield six tons of dry matter per acre, cut once it would certainly yield much less. Or take the case of cocksfoot; this springs so quickly in the aftermath that the foliage may shoot up six inches almost in as many days, whereas there would be no such growth were the hay not cut over. It is a matter of observation, too, how quickly red clover springs up after cutting, and trees and shrubs which may be growing only a few inches annually when unrestrained may send up stool shoots several feet in length if cut over. It is difficult, however, to bring the question to the test of figures. I have tried to do so by cutting over an area at short intervals by means of a lawn mower, but the presence of extraneous matter, especially worm-castings, vitiated the results.

If there is any doubt as to the greater weight of dry matter produced under a system of grazing, there can be none in respect of its digestibility. This would appear to be the reason why sheep and cattle will fatten on a pasture, whereas the animals would only remain in store condition on the herbage if made into hay.

At one time experiments on the improvement of pasture took the form of temporarily enclosing an area, to which different methods of treatment were applied and of determining the results in terms of hay. Supplementary to such quantitative determination, chemical analysis and botanical separations were often made, but it is evident from the work of the investigators already quoted that the results so obtained may be a very unreliable index of the feeding value of the herbage. In any case the competition between the various classes of plants may be very different in a hay field and in a well-grazed pasture. Again, in a hay field the produce is reaped and cleared off with all the plant food which it contains. In a pasture, on the other hand, there is the daily conversion of vegetable substance into manure and its immediate return to the land. Reflections of that sort induced me in 1896 to arrange a series of experiments where a direct appeal was made to the animal. We all know that in a lot of animals there are certain individuals which possess idiosyncrasies which result in their thriving better or worse than the others. By careful selection, however, and especially by keeping them under observation for a probationary period, this objection may be largely eliminated. The greater the number of animals the more completely is any disturbance due to individual peculiarities got rid of, and for this reason sheep are usually employed in preference to cattle. No one who looks into the details of these 'manuring for meat' experiments can doubt that, not only in broad outline, but even in the finer details, the results are per-

[21] 'Accumulated fertility in Grass Land in consequence of phosphatic manuring,' *Jour. Board of Agric.*, September 1914 and March 1916.

fectly reliable. Involving as they do considerable outlay on fencing, water, weighing machines, etc., and necessitating the use of large areas of uniform land, such experiments were not likely to be undertaken with great frequency, but I have been able to find reports of nine in England,[22] twelve in Scotland,[23] two in Ireland,[24] and one in New Zealand.[25] Two of them are situated at Cockle Park, of which the original in Tree Field has now completed its twenty-third season, while the other in Hanging Leaves has a record of sixteen years.

I propose now to make a brief general survey of the more salient results of this work.

The outstanding feature of these experiments is the great and profitable effect of phosphates. In this material the farmer is placed in possession of an agent of production whose effects on the output of meat, milk, and work from the pastures of this country are only limited by the supplies. In many cases the increase of meat is trebled and even quadrupled, with a return on the original outlay that runs into hundreds per cent. As between the various sources of phosphate there is unmistakable evidence that basic slag is the most effective, not only in respect of aggregate yield of meat, but also, and more particularly, when the net financial return is considered. This conclusion is also reached by Carruthers and Voelcker in a long series of pasture experiments carried out in 1896-9 for the Royal Agricultural Society of England.[26] In these experiments, however, the effects were only estimated by occular inspection. The primary effect of phosphates is due to the marked stimulus that they give to the growth of clovers and other Leguminosæ, and as these plants revel in a non-acid soil the alkaline character of basic slag appears exactly to suit their requirements. It seems highly desirable that a 'manuring for meat' experiment should be conducted with raw phosphates, whose effects on pasture seem distinctly hopeful. Gilchrist dressed a pasture in Northumberland with equal quantities of phosphoric acid derived respectively from basic slag, Belgian and Algerian phosphate, and two and a half years later he reported from occular observation 'that when such mineral phosphates are as finely ground as basic slag the phosphates they contain may be equally effective.' It must be said, however, that this opinion is hardly borne out by the quantitative results obtained on an adjoining meadow where the weight of hay produced by basic slag was distinctly greater than that grown on the plots dressed with the other two phosphates.[27]

In regard to the quantity of phosphatic manure that can most effectively be employed per acre, it would appear that in the case of inferior pasture a heavy initial dressing, say 200 lb. of phosphoric acid or more per acre, is likely to be nearly twice as effective as half this dressing, and therefore actually much more profitable. To secure the best results the Leguminosæ must be rapidly brought up to their maximum vigour, so that they may fully occupy the ground before the grasses have had time to react to the effects of the accumulated nitrogen.

One of the most striking results of these pasture experiments is the long period over which the action of phosphates persists. Even at the end of nine years the meat-producing power of half a ton per acre of basic slag is far from being exhausted. It is not suggested that this persistent action of slag—and no doubt this applies also to any other effective phosphate—is due to unappropriated residues. It is much more probably due to two other causes; (*a*) to the fact that on a pasture in contrast to a meadow manurial elements are kept in

[22] 'Guide to Experiments at Cockle Park for 1918' (Bulletin No. 27). *Jour. Bath and West Soc.* 1910. Cambridge Guide to Experiments, 1907. *Supplement No. 5 to Jour. Board of Agric.*, 1911. Wakerley, 'Manuring for Milk'; Midland Agricultural and Dairy Institute, 1912.

[23] *Trans. High. and Agric. Soc.* 1905 and 1908. Wright, 6th and 10th Reports on Experiments, West of Scot. Agric. Coll. 1905 and 1911. Greig, *Bulletin No.* 16 *of Aberdeen and North of Scot. Coll. of Agric.*

[24] *Journal of the Department of Agric. for Ireland*, September 1919.

[25] *New Zealand Journal of Agriculture*, 1919, p. 15.

[26] Carruthers and Voelcker, 2nd Report on the Grass Experiments conducted by the Society, *Jour. Roy. Agric. Soc.* 1900, p. 116.

[27] Gilchrist, *Jour. Newcastle Farmers' Club*, 1917.

circulation from the soil to the plant, and from the plant to the animal, and so, to a large extent, back to the soil again; and (*b*) to the accumulation of nitrogen in the form of humus. Poor unprofitable grass is chiefly associated with clay, and it is fortunate that it is precisely on such land that clover responds so markedly to phosphatic manuring. But conspicuous results have also been obtained on deep peat,[28] on light stony loam,[29] on thin chalk,[30] and on chalk covered by clay with flints.[31] Middleton has very fully discussed the conditions under which phosphatic dressings may be expected to give results [32] and ascribes an important place to soil moisture, on which white clover is directly very dependent. The only conspicuous case of failure of phosphates to improve pasture was encountered in Norfolk, where a 'manuring for mutton' experiment was started in 1901. The soil at that station was a hot dry sandy gravel containing 60 per cent. of sand, and there both basic slag and superphosphate were unable to produce any improvement. Wood and Berry attribute this result partly to the presence of abundant natural supplies of citric soluble phosphoric acid, but chiefly to lack of moisture.[33] In reporting on the R.A.S.E. experiments Carruthers and Voelcker in 1900 had already called attention to the dependence of basic slag on soil moisture.[34].

We may now look at the effect of supplementing phosphates with certain other substances. And, first of all, as regards potash. At most of the manuring-for-mutton stations both in England and Scotland there was a plot devoted to the elucidation of the effect of this substance, and although in the great majority of cases the phosphates-plus-potash plot has shown more live-weight increase than phosphates alone, it is only in very rare instances that the gain has been a profitable one. Even on thin soil overlying chalk potash has had little action on pastures. There are several rather conspicuous instances of quite moderate dressings of potash doing positive harm. Thus, at Cockle Park, whereas potash gave an appreciable increase in live weight in the first nine years, it proved positively and progressively injurious during the next two six-year periods. Even on a 'light stony loam' in Perthshire Wright found that although in the first two years potash when added to slag gave a conspicuous return, in the next three years 'the advantage was wholly with the slag alone plot.' The most notable beneficial effect of potash was obtained in Dumfries-shire on a station where the mineral soil was overlaid by ten feet of peat.[35] There the use of kainit supplying 100 lb. of potash per acre at the beginning of the experiment has in seven years produced 70 per cent. more meat than phosphate (slag) alone, while the financial gain has been improved by nearly 50 per cent.

Potash has had great influence both on the yield and composition of the hay on the meadow at Rothamsted, and it would seem that this substance has more effect on a meadow than on a pasture. The reason is probably to seek in the fact that in a pasture the top layers of the soil are constantly being enriched by the potash brought from the subsoil by plants and returned through their excreta. In any case, pasture plants on clay soil are in possession of abundant supplies of potash, and it is only where pasture occupies sandy, gravelly or peaty soil that this manurial element need be seriously considered.

Lime as an addition to superphosphate was tested at the three original manuring-for-mutton experiment stations, a total of 30 cwt. per acre being applied

[28] Wright, Report on Experiments on the Improvement of poor permanent pasture by manuring, *Bulletin No.* 54, *West of Scot. Coll. Agri.* 1910, p. 173.

[29] *Ibid.*, p. 187.

[30] Somerville, 'Poverty Botton,' an Experiment in increased Food Production, Miscellaneous Publications of the Board of Agriculture, 1918.

[31] Somerville, 'Influence on the Production of Mutton of Manures applied to Pasture,' *Suppl. Jour. Board of Agric.* 1911, p. 11.

[32] Cambridge University Dept. of Agric., *5th Annual Report on Experiments*, p. 13; and the 'Improvement of Poor Pastures,' *Jour. Agric. Science*, vol. i., p. 122.

[33] Wood and Berry, 'Soil Analysis as a Guide to the Manurial Treatment of Poor Pastures,' *Jour. Agric. Science*, vol. i., p. 114.

[34] *Op. cit.*, pp. 131-2.

[35] *Bulletin No.* 54 *of the West of Scotland Coll. of Agric.*, 1910.

in three dressings in nine years. A noticeable effect was produced at all stations, and at two of them the gain was a profitable one. The effects of lime can be followed for twenty-one years at Cockle Park, where the soil naturally contains 0·59 per cent. of calcium carbonate. During that period an aggregate of five and a half tons per acre was applied in seven dressings, the phosphate to which it was added being superphosphate in the first nine years and basic slag in the next twelve. The area receiving the lime was the same throughout. The action of the lime has proved to be a progressively decreasing one. On the average it produced an annual increase of 22 lb. live weight in the first nine years, and of 8 lb. in the next six years, whereas in the concluding six years of the period it has actually caused a reduction in live weight of 8 lb. per acre per annum. From these figures it would seem that lime has had more effect when used with superphosphate than when basic slag was employed. But already at the end of the ninth year, up to which time superphosphate was alone employed, the effects of lime were noticed to be declining at all the stations, a fact to which I called attention in reporting in 1911 on the influence on the production of mutton of manures applied to pasture,[36] where it is stated 'that in the penultimate and last years [of the first nine] the beneficial action of lime seems to be on the wane,' and where the opinion is expressed 'that the lime is acting rather as a liberator of inert nitrogen than as a direct plant food.' It would appear that this conclusion is confirmed by the experiences of later years. It would seem therefore that Wood and Berry's suggestion in the case of poor pastures is justified—namely, that 'the limit for calcium carbonate below which liming may be expected to be profitable is probably below 0·25 per cent.' [37]

The action of lime on grass land is a large subject, too large, in fact, to be exhaustively pursued here. But I may call attention to a series of experiments which I started on meadow land in Cumberland in 1895, and which have been reported on on several occasions.[38] At certain stations the use of 500 lb. per acre of caustic lime five times in eight years as an addition to a 'complete' manure has markedly decreased the hay crop, and it would appear that this dressing has exceeded the necessities of these soils in respect of 'lime requirement' in the sense of the term as employed by Hutchinson and Maclellan,[39] and that the stage of 'partial sterilisation' has been reached. Against the validity of this suggestion, however, there is the fact that the depressing influence of the lime was manifest in the first year. While there is evidence that lime as an agent in the improvement of pasture is a substance to be used with caution, it would appear that where there is a large accumulation of sour humus it is only through the use of lime that this can be got rid of, and the way thereby prepared for further improvement by the use of phosphates.

The addition to superphosphate of moderate dressings of nitrogen in the form of sulphate of ammonia or of nitrate of soda was tried at the three main manuring-for-mutton stations, and at two others. There is no need to go into a detailed discussion of the results. The evidence is overwhelmingly against the use of nitrogen on pastures. It undoubtedly stimulates the vigour of the non-leguminous herbage, but this reacts on the growth of the clovers, with the result that the production of meat is sometimes, as at Cockle Park, actually and substantially reduced.

At the three original stations dissolved bones were also tried, the comparison being with equal quantities (200 lb. per acre in nine years) of phosphoric acid derived respectively from basic slag and superphosphate. The dissolved bones supplied in addition from about 30 to 40 lb. of organic nitrogen. All manures were applied as to half in the first year, and, as to the other half, at the commencement of the fourth season, the experiment being continued for nine years

[36] *Supplement No. 5 of the Jour. Board of Agric.*, p. 50.

[37] *Op. cit.*, p. 117.

[38] Somerville, *Eighth Annual Report on Experiments, in the Counties of Cumberland, Durham and Northumberland*, p. 28. T. H. Middleton, *Tenth Annual Report*, p. 87. D. A. Gilchrist, *Eleventh Report*, p. 26.

[39] H. B. Hutchinson and K. Maclellan, *Jour. Agric. Science*, vol. vi., p. 302, and *ibid.*, vol. vii., p 73.

at Cockle Park and Sevington (Hants) and for eight years at Cransley (Northants). At Cockle Park slag acted substantially better than dissolved bones, though the latter surpassed the effect of superphosphate; at Sevington dissolved bones proved inferior to both the other manures; while at Cransley the position was reversed. But when the cost is considered there is no question of the superior merits of basic slag. This superiority is continued and emphasised at Cockle Park where the experiments are now at the end of their twenty-third year. A similar result was also obtained in the series of pasture experiments conducted by the Royal Agricultural Society of England already referred to. There dissolved bones or bone meal was tried at ten centres, with the result that 'in Herefordshire some benefit was observed, but in the other places no real improvement could be detected as compared with the unmanured part of the field. So far as these investigations go, therefore, they indicate that no further experiments need be made with bones on pasture land.'[40]

With these results before us it is needless to pause to consider whether the comparative failure of bones, dissolved or raw, is due to the inferior quality of their phosphate, or to the fact that they supply the land with nitrogen.

A form of pasture improvement which has had, and still has, much support amongst farmers is feeding with cake. The manure applied to the land through cake residues is a 'general' manure, supplying nitrogen, phosphates, and potash, of which that which has the highest value attached to it is the nitrogen. At eleven of the stations in England and Scotland reported on in the Supplement to the 'Journal of the Board of Agriculture' in 1911,[41] linseed or cotton cake, or a mixture of these cakes, was used for two, four, or five years, and at every one of them the live-weight gain secured was insufficient to pay for the outlay, the debit balance per acre per annum being in one case nearly a pound. In connection with the improvement of pasture, however, it is the residual effect of the cake that has most interest. This matter was put to the test at eight of the manuring-for-mutton stations in the following manner. At the three original stations cake was fed all through the season for two years, and none given for the next four. At five of the other stations cake was fed for two or four years, and was then suspended for one, two, or three years. In this way the improvement of the herbage effected during the years when cake was fed had an opportunity of manifesting itself in the form of live-weight increase in the years immediately succeeding, when no cake was given. In every case the residual effect was found to be appreciable, having a money value per ton of cake consumed of as much as 4*l*. 14*s*. at one station, and 3*l*. 11*s*. at another, the average for the three stations where the residues were followed for four years being fully 3*l*. per ton, a figure which is of the same order as, though somewhat higher than, those adopted by Voelcker and Hall in their revised table of 1902.[42]

At Cockle Park on Tree Field the question of the immediate and residual effects of decorticated cotton cake has been pursued through twenty-one years. After the first stage of nine years, cake was fed for three years, and its residues tested for the succeeding three years, and similarly in the next period of six years. In this connection I cannot do better than quote from Gilchrist's Reports. Commenting on the second six-years period, he says, 'Decorticated cotton cake fed to the sheep on plot 1 in the first three years gave a small gain in these years, but throughout the six years the average annual gain amounts to only 9*d*. an acre.'[43] As to the third period of six years he reports, 'Decorticated cotton cake fed to the sheep on plot 1 in the first three years has resulted in an annual loss of 11*s*. 9*d*. an acre. . . . It is notable that the cake has not given a profitable return from the sheep in the years when it was fed to them, and it has had little unexhausted value in the later years. Nitrogen from the cake has had the same effect on the herbage of this plot as nitrogen from the nitrate of soda on plot 9, and the herbage is still of a coarse and benty character.'[44] This, on land which has had about 2½ tons per acre

[40] *Op. cit.*, p. 135.
[41] *Op. cit.*, p. 22.
[42] *Jour. Roy. Agric. Soc. Engl.*, vol. 36, p. 111.
[43] 'Guide to Experiments for 1917,' p. 13.
[44] 'Guide to Experiments for 1918,' p. 15.

of a rich cake fed at intervals during twenty-one years is a poor showing, and justifies the conclusion that as an ameliorative agent cake occupies a low position as compared with an effective phosphate like basic slag.

A method of improvement of poor pasture that deserves notice consists in scattering the seed of a 'renovating' mixture over the surface, usually with concurrent harrowing, rolling, and manuring. This procedure was practised in the series of experiments conducted by the Royal Agricultural Society of England, the seed mixture consisting of four natural grasses in addition to white clover and yarrow.[45] In their final report Carruthers and Voelcker stated that re-seeding had not been successful, a result which they thought was 'entirely due to the prevalence of dry seasons, the germinating plants being killed before they could get hold of the soil.' A more successful result is reported by Middleton,[46] who on a poor pasture on clay soil in Essex, sowed, in the spring of 1903, 12 lb. per acre of wild white clover seed, with and without basic slag, kainit, and lime, this treatment being unaccompanied by harrowing. There were no Leguminosæ naturally present in the field. Helped by abundant rain in the summer of 1903, when in the London area in June 'rain fell without cessation from midday on the 13th to midnight on the 15th; and at Camden Town the total in fifty-eight hours amounted to nearly $3\frac{1}{2}$ inches,'[47] the seed germinated well, and 'in 1904 the results were very marked.' It was, however, only when the seeding had been accompanied by basic slag that 'there was the luxuriant growth which one expects in pastures where Leguminosæ are present.'

Middleton came to the conclusion that 3 lb. per acre of white clover seed would have been enough, and that ordinary white clover seed, as contrasted with seed from the wild plant, would serve the purpose. Middleton carried out this experiment in the early days of 'wild white,' and probably he would now agree with the suggestion that this variety possesses properties which mark it off rather sharply from the cultivated variety, and that the two, for permanent purposes, are not interchangeable. I also have reported on an experiment where renovating a thin poor pasture with 6 lb. per acre of wild white clover seed was entirely successful, and here, too, the beneficial effects were only secured in the presence of basic slag.[48]

It would appear, therefore, that where the herbage of a pasture is thin, so as to permit of a considerable proportion of the seed reaching the soil, and especially in the absence of natural Leguminosæ, renovation through the agency of wild white clover seed, with concurrent phosphatic manuring, is likely to be successful. Drought, however, at a critical stage of the growth of the young plants may prove fatal, but such a contingency will be best avoided by seeding in early autumn rather than in spring.

The many experiments, and ordinary farming experience, show clearly how poor pastures may be profitably improved in the first instance, but an important matter still remains to be discussed—namely, the means to be adopted to maintain the improvement.

When a responsive pasture is treated, for the first time, with say half a ton of basic slag per acre, the effects reach their maximum usually in the third season. From then onwards there is a steady diminution in the yield, though even after nine years from the time of the initial dressing the improvement is far from being exhausted. At Cockle Park, for instance, the plot dressed once with half a ton of slag was, at the end of nine years, producing three times as much mutton as the continuously unmanured ground, while at Sevington and Cransley the yield, at the end of nine and eight years respectively, was 70 to 80 per cent. greater. None of the other stations was carried on for so long a period, but up to the end of the sixth year most of them show residual fertility which is as great as the original rental value of the land.[49] That is a very important result, but in the interests of the country it is still

[45] *Jour. R.A.S.E.*, 1898, p. 148.
[46] *Jour. Agric. Science*, vol. i., p. 136.
[47] *Ibid.*, 1913, p. 415.
[48] 'Poverty Bottom,' p. 6.
[49] *Supplement No. 5 to Jour. Board of Agric.*, 1911, p. 28.

more important to endeavour to secure that the level reached at the period of maximum productivity shall be maintained.

Some information on this point is furnished by the three manuring-for-mutton stations at Cockle Park, Sevington, and Cransley. At each of these places a plot was dressed with 100 lb. of phosphoric acid derived from slag, and for the fourth season thereafter the dressing was repeated, nothing more being applied for the succeeding six years. At each of the stations there was an immediate response; at Cockle Park the repeated dose acted considerably better than the first; at Cransley the effects of the two dressings were practically identical, only at Sevington was the effect of the first dressing considerably better than that of the second.[50] This subject can be followed for twenty-one years at Cockle Park, where, since the end of the ninth year, 10 cwt. per acre slag (200 lb. P_2O_5) are applied every six years to Plot 3, as contrasted with 5 cwt. (100 lb. P_2O_5) every three years to Plot 4, another plot receiving at the same time 100 lb. P_2O_5 in the form of 7 cwt. of superphosphate. The information we want is as to whether these dressings of phosphates have been able to maintain the high state of productiveness which we know was secured by the initial doses of these substances. The figures bearing on this point are brought together in the accompanying table.

Average annual Live-Weight increase per acre for the same 3-year periods.

——	No Manure	5 cwt. Slag every 3 years[51]		7 cwt. Super. every 3 years[51]	
	Actual Increase	Actual Increase	Gain due to Slag	Actual Increase	Gain due to Super.
	lb. L.W.	lb. L.W.	lb. L.W.	lb. L.W.	lb. L.W.
1st dose of manure .	46	90	44	88	42
2nd ,, .	36	131	95	126	90
3rd ,, .	23	115	92	106	83
4th ,, .	24	86	62	98	74
5th ,, .	20	98	78	103	83
6th ,, .	23	108	85	101	78

Average annual Live-Weight increase per acre for the same 6-year periods.

——	No Manure	10 cwt. Slag every 6 years[52]	
	Actual Increase	Actual Increase	Gain due to Slag
	lb. L.W.	lb. L.W.	lb. L.W.
1st dose of manure . .	41	137	96
2nd ,, . .	23	117	94
3rd ,, . .	22	112	90

It will be seen, in the first place, that the production of the unmanured plot has manifestly declined from the earlier years, a result partly due to the lighter stocking and partly to the shorter grazing season. Confining attention for the moment to the left-hand section of the table, it may at once be said that the high level of productivity induced by the second dressings both of slag (5 cwt.) and superphosphate (7 cwt.) has not been maintained, the cause being probably due, in large part, to a six-year interval occurring between the second and third doses. But there is a distinct tendency for the live-weight increase to rise in the later stages, and, on the whole, it may be said to be conclusively demonstrated

[50] *Supplement No. 5 to Journ. Board of Agric.*, 1911, p. 36.

[51] The 5 cwt. slag and 7 cwt. super. were applied every 3rd year, except that there was an interval of 6 years between the 2nd and 3rd doses.

[52] The slag was applied every 6th year, except that there was an interval of 9 years between the 1st and 2nd doses.

that on this particular class of land fertility has been well maintained by moderate dressings of slag or superphosphate at three-year intervals.

As regards the larger dressing of slag (lower section of table) it will be seen that here also absolute productivity is not maintained at the high level of the earlier years, though as between the ninth and fifteenth years the reduction is very slight. But comparing the production on the manured and unmanured land it will be seen that in these three tests the proportionate increase of meat as a result of repeated doses of phosphates is actually greater at the end of 21 years than it was in the beginning, the ratio rising from 2·3 :1 to 4·1 :1. In other words, for every pound of meat produced on the unmanured land 5 lb. are being produced on the manured ground, and not only so, but the enhanced production is being secured at a cost which leaves a very large profit on the improvement.

The power of repeated moderate dressings of slag to maintain the improvement produced by a large initial dressing of this substance is well illustrated in another series of experiments commenced at Cockle Park in 1903. A field (Hanging Leaves) of poor pasture on clay was equally treated in 1898 with about 6 cwt. of slag per acre. No further treatment was given till 1903 when 4 plots, each 10·1 acres in extent, were fenced off, and to all of them 10 cwt. per acre of slag was given. Since that time a supplementary dressing of 5 cwt. per acre of slag has been given to Plot 1 every 3 years, with the result that at the end of 15 years of this treatment the production of live-weight increase (in this case both cattle and sheep) is nearly as high (200 lb. per acre, average 3 years 1915-17) as at the stage of maximum production (206 lb. per acre, 1906-8). Here, as on Tree Field, under the influence of slag the meat produced is nearly five times as great as on the untreated ground.[53]

Another plot, No. 2, is concerned with the question as to whether cake can be profitably fed to cattle and sheep on land which has first been graded up with a liberal dressing of basic slag. Both Plots 1 and 2 have had the same amount of basic slag since 1898 (36 cwt. per acre) applied at the same time, the only difference in the treatment being that the stock on Plot 2 have since 1904 consumed 3 cwt. of rough cotton cake per acre, except in 1917 when a mixture of palm-kernel and earth-nut cakes was substituted. The quantity consumed up to the end of 1917 is thus practically 2 tons per acre. The cake has in the aggregate in 14 years added about 470 lb. to the live-weight increase per acre produced by slag alone. This increase at present-day rates is valued at less than 9*l.*, to secure which the expenditure on cake is estimated at about 26*l.*, so that the direct and indirect effects of the cake have been extremely unprofitable. As a matter of fact, whereas slag alone gives an annual profit of more than 2*l.* per acre, the use of cake on slagged land reduces the profit to less than 1*l.* Clearly, therefore, cake-feeding on this class of land, which is receiving basic slag, is not a commercial success.

Another aspect of the same problem is dealt with on Plot 3. Both this plot and No. 1 received the same initial dressing of slag—namely, ½ ton per acre for 1903—the differential treatment since that year consisting in No. 1 receiving every 3 years 5 cwt. of slag, whereas No. 3 has had 3 cwt. per acre per annum of rough cotton cake fed upon it. The comparison, in fact, is between the feeding value (indirect) of 5 cwt. of slag and the feeding value (direct and indirect) of 9 cwt. of cotton cake. The results, with those on the other plots, are shown in the table on page 16.

For the first two years, when no supplementary slag had been applied, the cake appeared to give a good account of itself, but the first supplementary dressing of slag distinctly reduced the difference in the two sets of live-weight figures, after which the output of Plot 1 (slag) steadily improved, while that of Plot 3 (cake) as steadily, and more markedly, declined, until in the period 1915-17 the slag was producing 55 lb. per acre per annum more animal increase than the cake. It would appear therefore that the accumulated cake residues have had a positively injurious effect on the pasture, and that this effect is being accentuated as time goes on.

The fourth plot is concerned with the question as to the value of organic nitrogen in fish meal as compared with the nitrogen in cake residues. Plots 2

[53] Gilchrist, 'Cockle Park Guide,' 1919, p. 17.

Cockle Park, Hanging Leaves Experiment (All Plots received per acre about 6 cwt. Slag for 1898 and 10 cwt. for 1903).

	Plot 1.	Plot 2.	Plot 3.	Plot 4.
—	5 cwt. Slag every 3 years	Same as Plot 1, but also 3 cwt. Cotton Cake fed annually	Same as No. 2, but no Supplementary Slag	Slag (4 cwt.) and Fish Meal ($3\frac{1}{2}$ cwt.), supplying P_2O_5 and N equal to that contained in the Cake and Supplementary Slag of No. 2
—	Average L.W. gain per acre per annum	Average L.W. gain per acre per annum	Average L.W. gain per acre per annum	Average L.W. gain per acre per annum
1904–5	151	207	204	153
1906–8	206	251	227	225
1909–11	187	213	161	187
1912–14	189	210	150	190
1915–17	200	227	145	179
1918	218	242	142	167

and 4 got the same initial dressing of slag (10 cwt. per acre) for 1903, since which year the stock grazing on Plot 2 have eaten 3 cwt. per acre per annum of cotton cake. In addition, this plot has every 3 years (commencing with 1906) received 5 cwt. per acre of slag. Plot 4 has every 3 years received 4 cwt. per acre of slag and $3\frac{1}{2}$ cwt. of fish meal, the slag and fish meal combined being estimated to supply P_2O_5 and nitrogen equal to these substances contained in the 5 cwt. of slag and 9 cwt. of cotton cake given every 3 years to Plot 2. The cake plot (No. 2) has yielded in the aggregate of 14 years about 470 lb. more live-weight increase, but as the cost of doing so has been about 14*l*. the balance of profit is much in favour of Plot 4. As in the case of Plot 3 (cake alone after initial dressing of slag) the productivity of Plot 4 is distinctly on the down grade, and both as regards the live-weight increase and net returns it compares very unfavourably with Plot 1, which received the same initial treatment as regards slag, and subsequently was dressed at 3-year intervals with 5 cwt. of slag, instead of 4 cwt. of slag and $3\frac{1}{2}$ cwt. of fish meal. It seems to be quite clearly proved, therefore, that on such pasture land as Cockle Park the addition of nitrogen to phosphates is most detrimental, and no doubt for the reason that it encourages grass to the disadvantage of clover.

From this rapid survey of grass-land experiments the following conclusions may legitimately be drawn :—

1. That the quality of a pasture is not primarily dependent on its botanical composition, though, as a rule, the presence of white clover and other Leguminosæ is generally indicative of high feeding value.

2. That poor pastures, especially on clay soil, can be rapidly and profitably improved by the use of phosphates, especially basic slag.

3. That, as a rule, phosphates alone are necessary to effect and maintain the improvement, and that, of supplementary substances, potash and lime are occasionally worthy of attention.

4. That the improvement of poor pasture is very dependent on the presence of Leguminosæ, and especially of white clover.

5. That renovating with the seed of wild white clover may, in the absence of natural Leguminosæ, be a necessary preliminary or concurrent operation.

6. That cake can rarely be used at a profit, and that, as an agent in improving poor pasture, it occupies an unsatisfactory position.

7. That nitrogen, whether in the form of artificial manure, or as cake residues, when added to phosphates for pasture, is always unnecessary and frequently detrimental.

8. That, in the case of hay ~~on permanent~~ grass land, equal weights of produce may have very different feeding values.

9. That few forms of agricultural expenditure are more certain in their results than the judicious use of manures on grass land, and that the meat and milk producing capacity of the country can be largely and rapidly increased, with great pecuniary gain to the farmer, and still greater economic advantage to the nation.

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